ASTRONOMY

October 1980
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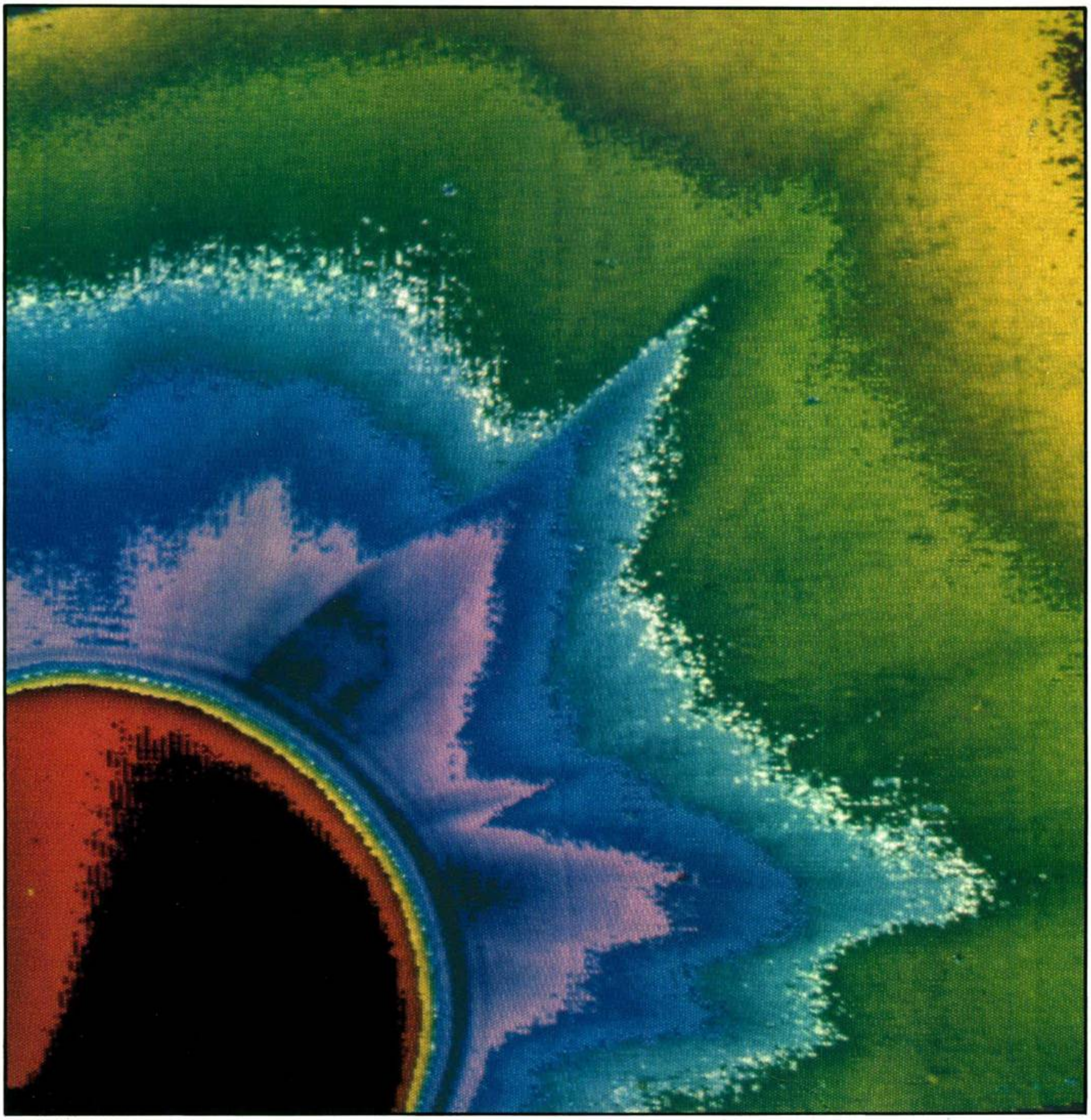
Space, Time, and Black Holes

How to Buy a Telescope for Your Child

Why All the Fuss about Quasars?



The Solar Corona from Space

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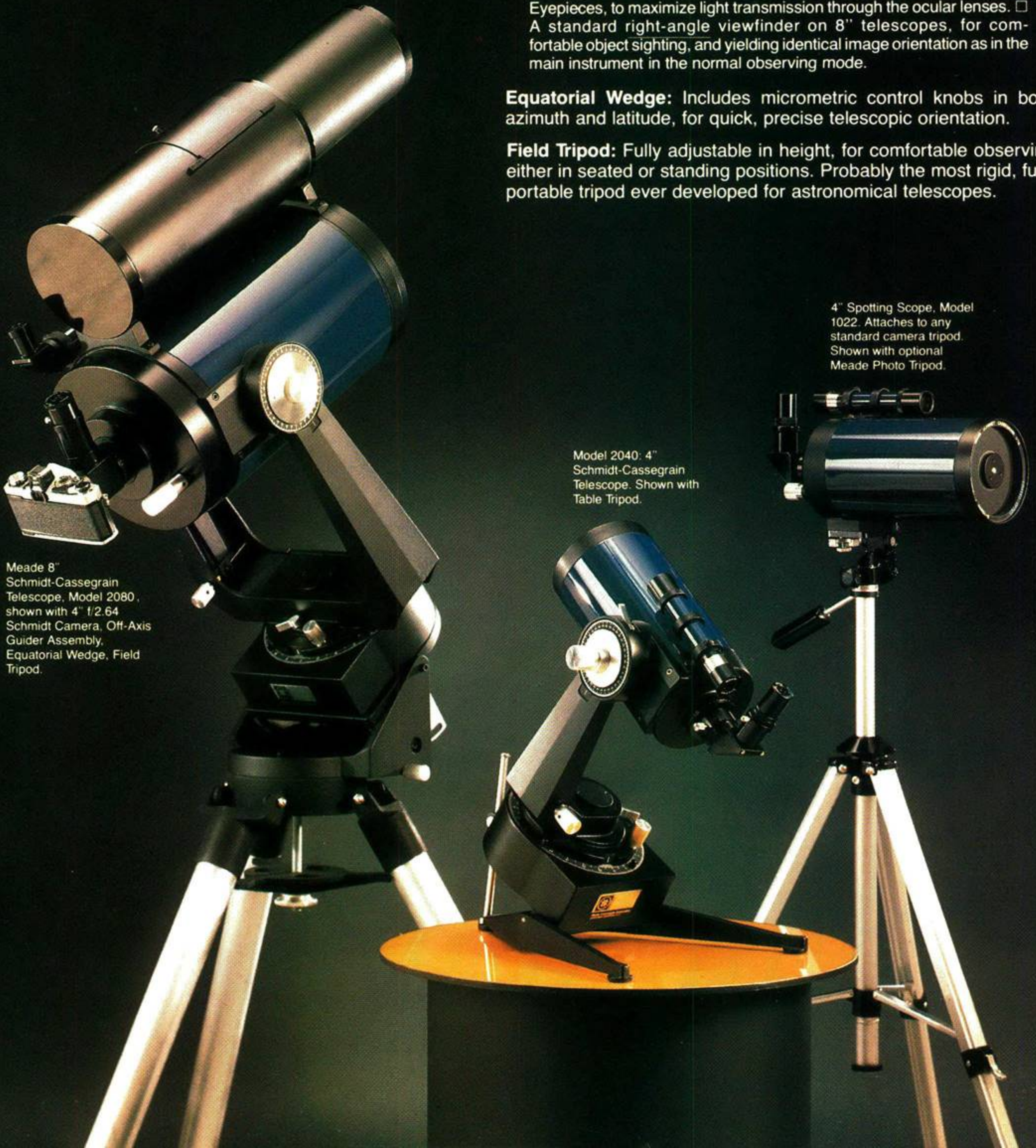

Meade 8" Schmidt-Cassegrain Telescope, Model 2080, shown with 4" f/2.64 Schmidt Camera, Off-Axis Guider Assembly, Equatorial Wedge, Field Tripod.

Model 2040: 4" Schmidt-Cassegrain Telescope. Shown with Table Tripod.

4" Spotting Scope, Model 1022. Attaches to any standard camera tripod. Shown with optional Meade Photo Tripod.

Schmidt-Cassegrains

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8" Schmidt-Cassegrain Telescope with Fork Mount ......Base Price	**785**
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Table Tripod 8"	**45**
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Model 1022: 4" Spotting Scope	**395**
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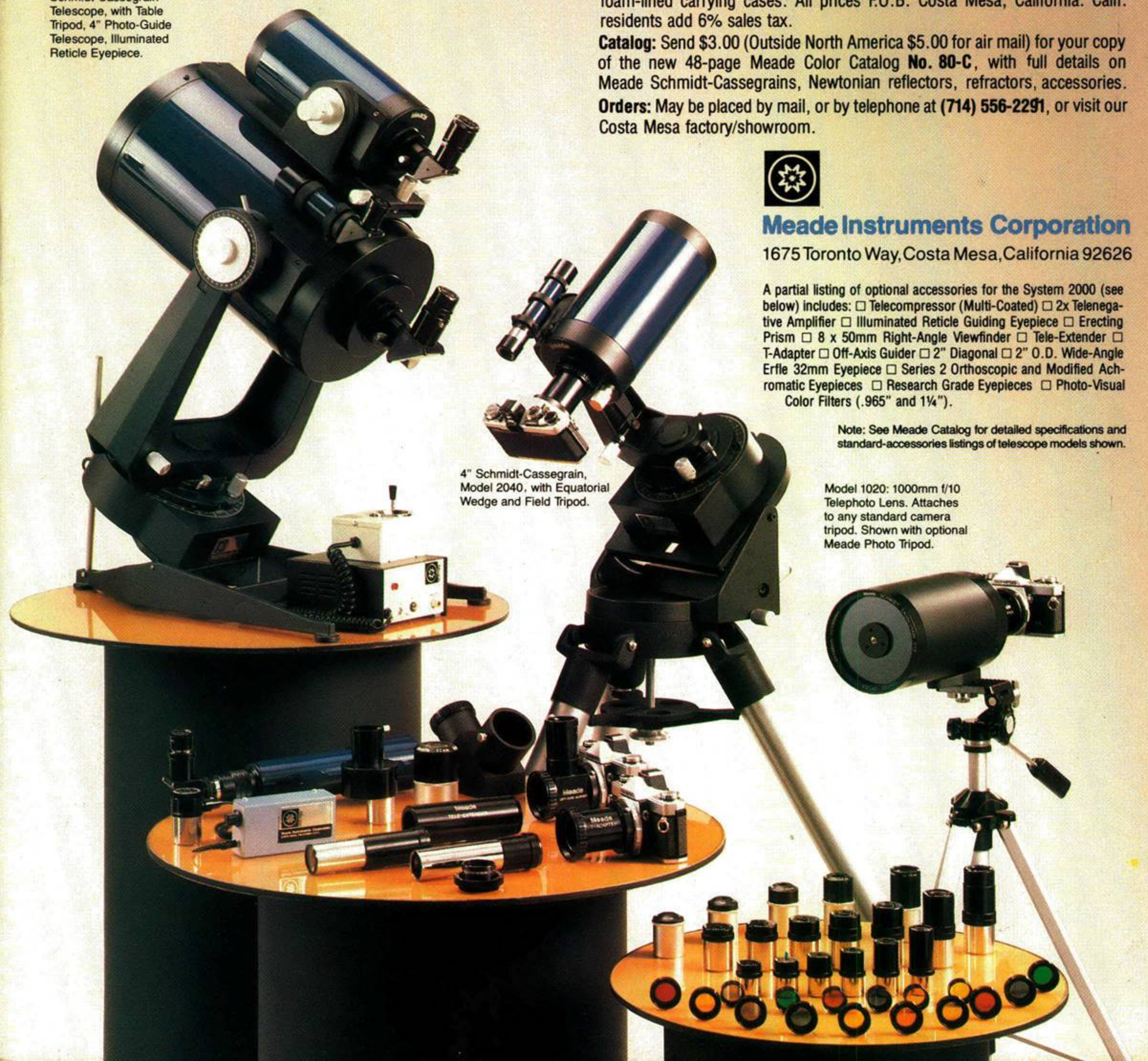
A partial listing of optional accessories for the System 2000 (see below) includes: ☐ Telecompressor (Multi-Coated) ☐ 2x Telenegative Amplifier ☐ Illuminated Reticle Guiding Eyepiece ☐ Erecting Prism ☐ 8 x 50mm Right-Angle Viewfinder ☐ Tele-Extender ☐ T-Adapter ☐ Off-Axis Guider ☐ 2" Diagonal ☐ 2" O.D. Wide-Angle Erfle 32mm Eyepiece ☐ Series 2 Orthoscopic and Modified Achromatic Eyepieces ☐ Research Grade Eyepieces ☐ Photo-Visual Color Filters (.965" and 1¼").

Note: See Meade Catalog for detailed specifications and standard-accessories listings of telescope models shown.



Model 2080: 8" Schmidt-Cassegrain Telescope, with Table Tripod, 4" Photo-Guide Telescope, Illuminated Reticle Eyepiece.

4" Schmidt-Cassegrain, Model 2040, with Equatorial Wedge and Field Tripod.

Model 1020: 1000mm f/10 Telephoto Lens. Attaches to any standard camera tripod. Shown with optional Meade Photo Tripod.

ASTRONOMY

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Cover: Blasts of hot (4 million degree) gases stream away rapidly from a turbulent solar corona, as seen in this computer-processed image taken by NASA's Solar Maximum Mission spacecraft. The spike stretching toward the upper right was traced outward for over a million miles from the Sun's surface. The Earth, to scale, would be about as large as the smallest specks in the image. (See AstroNews, page 58.) NASA photograph. This page: The famed Crab Nebula, (M-1) in Taurus, photographed by Bill [illegible]rg.

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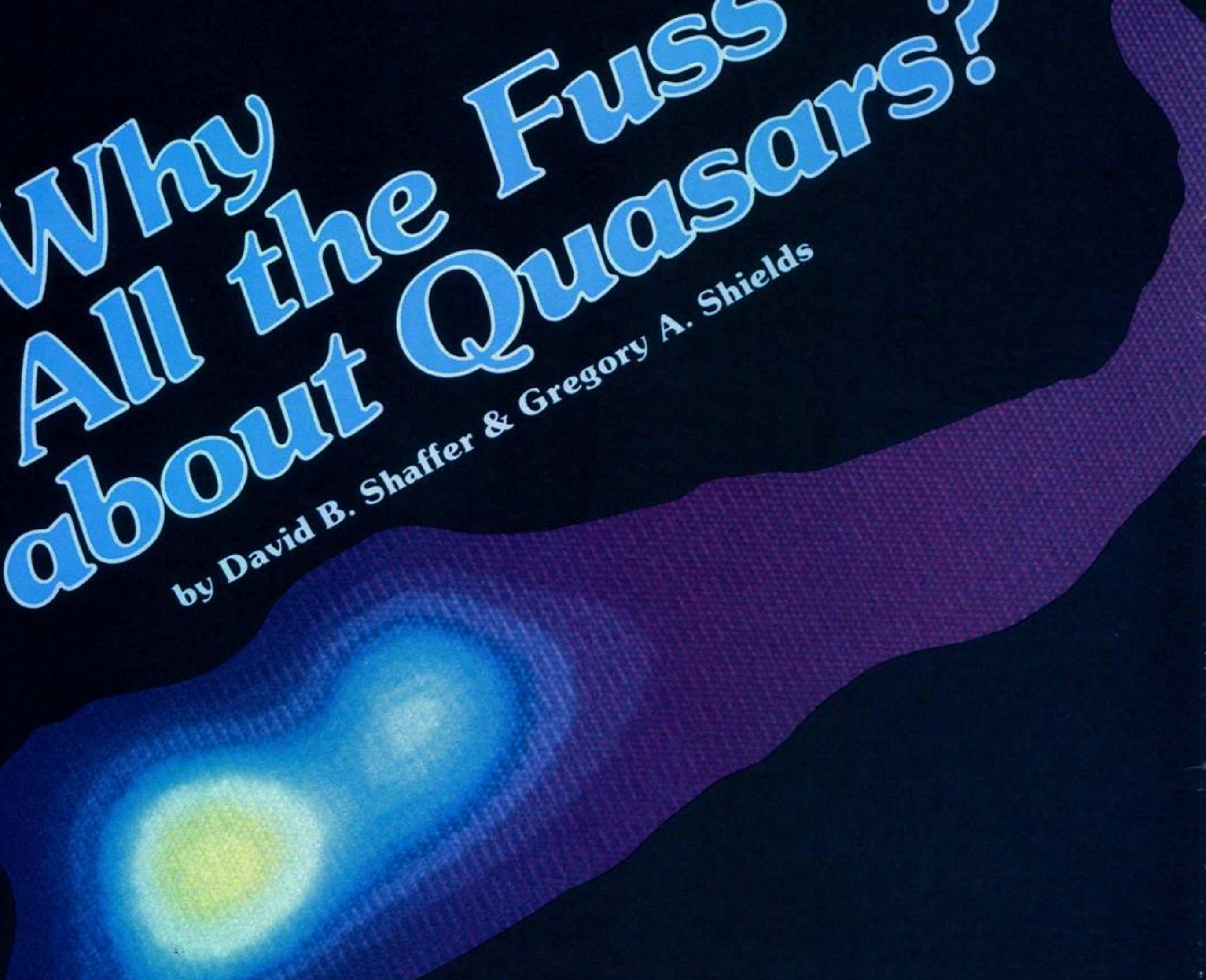
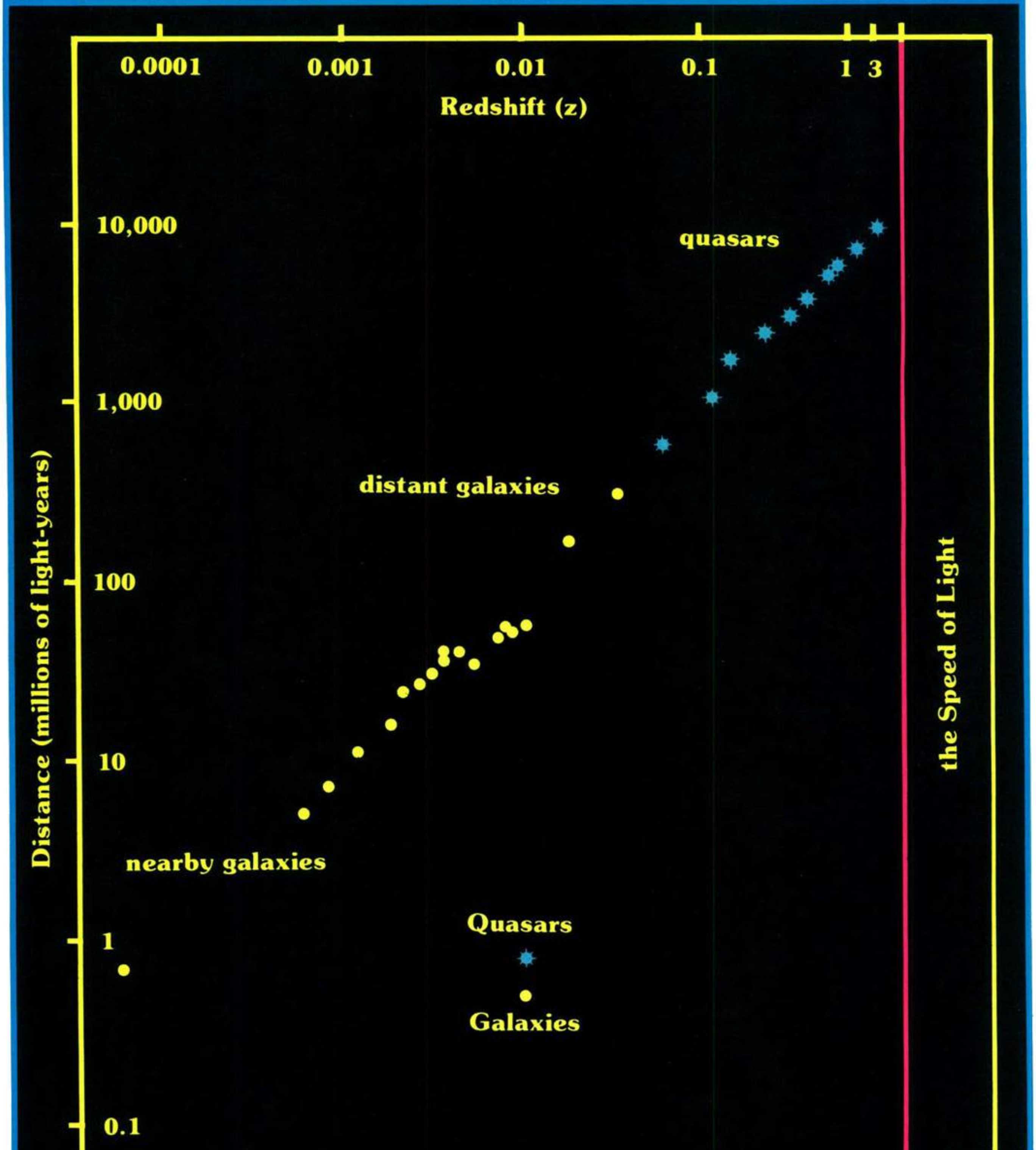
Why All the Fuss about Quasars?

by David B. Shaffer & Gregory A. Shields



Cosmology is at once the most useless and the most absorbing of all astronomical endeavors. Of no practical significance whatever (and perhaps valuable just because of this), it is a great intellectual adventure deep into the unknown. Astronomers hope that quasars, such as that seen here in a synthesized radio map, will tell about conditions and matter at the farthest reaches of the cosmos — and at the earliest moments of time. Photo courtesy of the Max-Planck-Institut fuer Radioastronomie.

The Hubble Diagram



Quasars fascinate. You can hardly pick up a book or periodical without finding yourself immersed in QSOs, jets, megaparsecs, and other arcane jargon of professional astronomers. Clearly something very exciting is going on, but what is it? Why are those tiny points of light called quasars so all-mighty interesting?

Consider this: Quasars are the most powerful sources of energy in the entire universe. They broadcast prodigious amounts of power in most of the kinds of radiation known to physics. Their energy may come from giant black holes. And they may allow us to probe out to vast distances in space and back to remote times in the history of the universe.

Naturally, the details don't stand out clearly. There's a lot to be unraveled yet — even now, nearly 20 years after their discovery, we still lack a basic understanding of them — but astronomers have made a tantalizing measure of progress. In the next few years, this picture should clear up considerably, thanks to improved instruments such as the Space Telescope and the perseverance of theorists who aren't going to be happy until they've solved the mysteries of the quasars. Eventually, perhaps by the end of the century, we'll arrive at a thorough understanding of one of Nature's most remarkable creations.

The Radio Beginnings

The initial discovery of quasars was a coup for the radio astronomers. As that branch of astronomy developed in the years after World War II, most radio sources were found to be broad, extended sources of emission. Nevertheless, a few resembled the point sources stars look like in an optical telescope. Finally, radio telescopes became good enough to pinpoint the objects so that astronomers could find them in conventional optical instruments. They looked exactly like ordinary stars. But when these objects' spectra were taken with a spectrograph, astronomers were dumbfounded. The spectra were totally unfamiliar, showing emission lines of hot gases that didn't seem to correspond to any known substance. Obviously differing from the normal stars they superficially resembled, these weird "stars" got dubbed quasi-stellar radio objects, a mouthful quickly shortened to "QSO" or "quasar."

Years passed. In 1963, a major breakthrough came when astronomer Maarten Schmidt found the spectral lines in the radio source 3C 273 were normal lines of hydrogen gas — but displaced toward the red end of the spectrum by an astoundingly large amount. Those unknown spectral lines which had so confused scientists were just those of ordinary elements, extraordinarily displaced.

Astronomers call spectral displacements toward the red part of the spectrum *redshifts;* those towards the blue, *blueshifts.* They express the change as a decimal fraction; 3C 273's redshift was 0.158, meaning that each line in the spectrum was displaced 15.8% toward the red relative to the laboratory standard.

A redshift or a blueshift indicates a *radial velocity,* a relative velocity between us (the observers) and the object in our line of sight. For example, light from the Sun's east side is slightly blueshifted (because that side is rotating toward us); the western edge is likewise slightly redshifted. The radial velocities of stars in a cluster help to tell an astronomer about the internal motions of a cluster. But the cosmological use for radial velocities is mind-boggling.

Some 55 years ago, cosmologist Edwin Hubble observed that the most distant galaxies had the largest redshifts, a result that established a cornerstone of modern cosmology, the expanding universe. He also realized that the observations could be inverted — with redshifts providing distances to galaxies. Their "absolute" distances have been increased greatly since Hubble's day, but his principle stands unshaken: The farther away an object is, the greater its redshift. Over the years since, the redshift has become a convenient cosmic yardstick for astronomers.

3C 273's redshift of 0.158 corresponds to a recession velocity of some 47,000 kilometers per second and suggests a distance of just under 3 billion light-years. Soon, observers found other QSOs having lines of normal elements displaced by even higher redshifts.

But there's a catch: How can we be sure that quasars obey a Hubble Law founded on galaxies? If some other mechanism were at work, quasars might not really lie at the huge distances their redshifts imply. This very problem is the nub of a controversy among astronomers. A minority feel that quasars' redshifts are not "cosmological," that is, quasars are relatively nearby and their redshifts are produced in some unknown way. Most astronomers, however, believe that the observations show quasars are a type of galaxy — admittedly unusual — and therefore obey Hubble's Law.

If the majority of astronomers are right — that quasars are distant — then quasars' power is stupendous. Considering the radio energy alone, we find quasars with luminosities of up to 10^{38} watts. In round figures, that's enough energy released in one second to supply the present U.S. energy demand for a billion billion years! What can power such prodigious outputs?

Astronomers believe that cosmic ray electrons generate the radio waves we observe from quasars. As these electrons move at nearly the speed of light around the object, through regions of space pervaded by its magnetic fields, they emit radio energy. Astrophysicists call this emission process *synchrotron radiation* because it was first described in conjunction with the laboratory particle accelerators called synchrotrons.

Their Tiny, Hot Centers

The radio waves from many quasars pour out of a very small volume at the center of the quasar. These emission centers have diameters ranging from a few to a few dozen light-years; their corresponding angular sizes are around 0.001″ (one thousandth of an arc second; the Moon looms 2 million times bigger in apparent diameter). Compared to full-blown

A clear-cut relationship exists between distance and recessional velocity for galaxies. Most astronomers think quasars lie at the immense distances their redshifts imply, which places them at the upper end of the line established by ordinary galaxies and Seyferts. Quasars are then seen as part of a sequence, perhaps evolutionary, extending from the Local Group galaxies to the farthest edge of the universe.

galaxies, these tiny sources are "compact." Galaxy-size sources or larger are called "extended."

Radio telescopes used singly have notoriously poor resolution when compared with optical telescopes, so to study these very small sources, radio astronomers had to exercise some ingenuity. Since resolution depends mainly on aperture, they have hooked up antennas separated by thousands of miles to provide very high resolution. This powerful technique is called VLBI, short for Very Long Baseline Interferometry. (See "Using Earth as a Radio Telescope," ASTRONOMY, October 1979.) It gives the resolution of a radio dish thousands of miles across.

The VLBI-determined structure of quasar 3C 345 shows a radio source around 50 or 60 light-years across with an emission region extending out to one side of the compact central region. But like 3C 345, about half the quasars studied in detail show a paradoxical phenomenon of expansion.

Measurements taken over the past decade show that the angular size of 3C 345's source has increased greatly. But this provokes problems because when we use the redshift of 3C 345 to compute its distance, the source appears to be expanding at about 7 times the speed of light! Since relativity flatly rules this out, there has to be some other explanation.

Fortunately, several straightforward interpretations — based on optical illusions that occur when things move close to, but still slower than, the speed of light — are possible.

One candidate is the so-called "flashlight" or "lighthouse" effect. Picture a flashlight sending out a beam of light while rotating. As the beam sweeps past distant clouds of gas or dust, they'll light up briefly. The more distant the clouds or the faster the beam rotates, the swifter the lit patch will appear to move. Eventually it could "travel" faster than the speed of light.

Beaming effects in radio sources are common. Radio and optical emission from quasar 3C 273 shows a prominent linear jet; the radio jet in galaxy NGC-6251 is even more spectacular. More than a million light-years long, the jet shows that the energy source has been squirting a stream of material — mostly hot gas — in the same direction for at least a million years. Any attempt to explain quasars must also explain the jets.

Many quasars and most radio galaxies also have extended sources of radio emission with sizes up to a few million light-years. The emission usually appears as two roughly equal components on opposite sides of the central object, as we see with Cygnus A. The radio lobes and the central object are almost perfectly lined up over a distance of several hundred thousand to a million or more light-years. No one is quite sure how the extended components are created or how they remain so *well defined*, but it appears that they are regions where the material ejected in the jets from the nucleus is plowing through the intergalactic medium.

In maps of Cygnus A and many other sources, there is a very small and weak radio source right in the middle of the parent galaxy or quasar. These nuclear sources are elongated and line up with the extended emission. Some of the energy of the nuclear jets channels its way out to the radio lobes in streams of highly-magnetized material. If this theory is correct, the extended sources have been built up slowly over millions of years as energy and material ejected from the central source "piles up" around the quasar.

At first, quasars were thought to be simple point-sources of emission, but high resolution radio interferometry changed all that. Now the picture has become much more interesting: lobes, wings, and other details of an intricate nature can be found in many quasars and radio galaxies. Scientists think the extensive structures build up when material thrown off collides energetically with the thin intergalactic medium. Artwork by Mark Paternostro.

You Name It, Quasars Make It

Radio waves are not the only kind of radiation emanating from quasars. At progressively higher frequencies — shorter wavelengths — their spectrum includes infrared, optical, ultraviolet, X-ray, and gamma-ray radiation. Roughly speaking, their power distributes itself equally all the way from infrared to gamma-ray frequencies.

Because the radiation at these wavelengths may have vital clues to understanding quasars hidden in it, and because our atmosphere hinders observations at ultraviolet, X-ray, gamma-ray, and some infrared frequencies, astronomers must send their instruments above it. The recent Einstein satellite, for example, carries an X-ray telescope to study quasars.

But still the question nags: How can one source generate all these various types of radiation? A promising theory proposes that the emission at infrared and all higher frequencies comes from a compact region at the center of the quasar, perhaps about a light-year across. It calls for swarms of cosmic ray electrons immersed in strong magnetic fields to emit infrared waves by means of the synchrotron radiation process. The synchrotron process also generates radio waves with less energetic electrons and weaker magnetic fields.

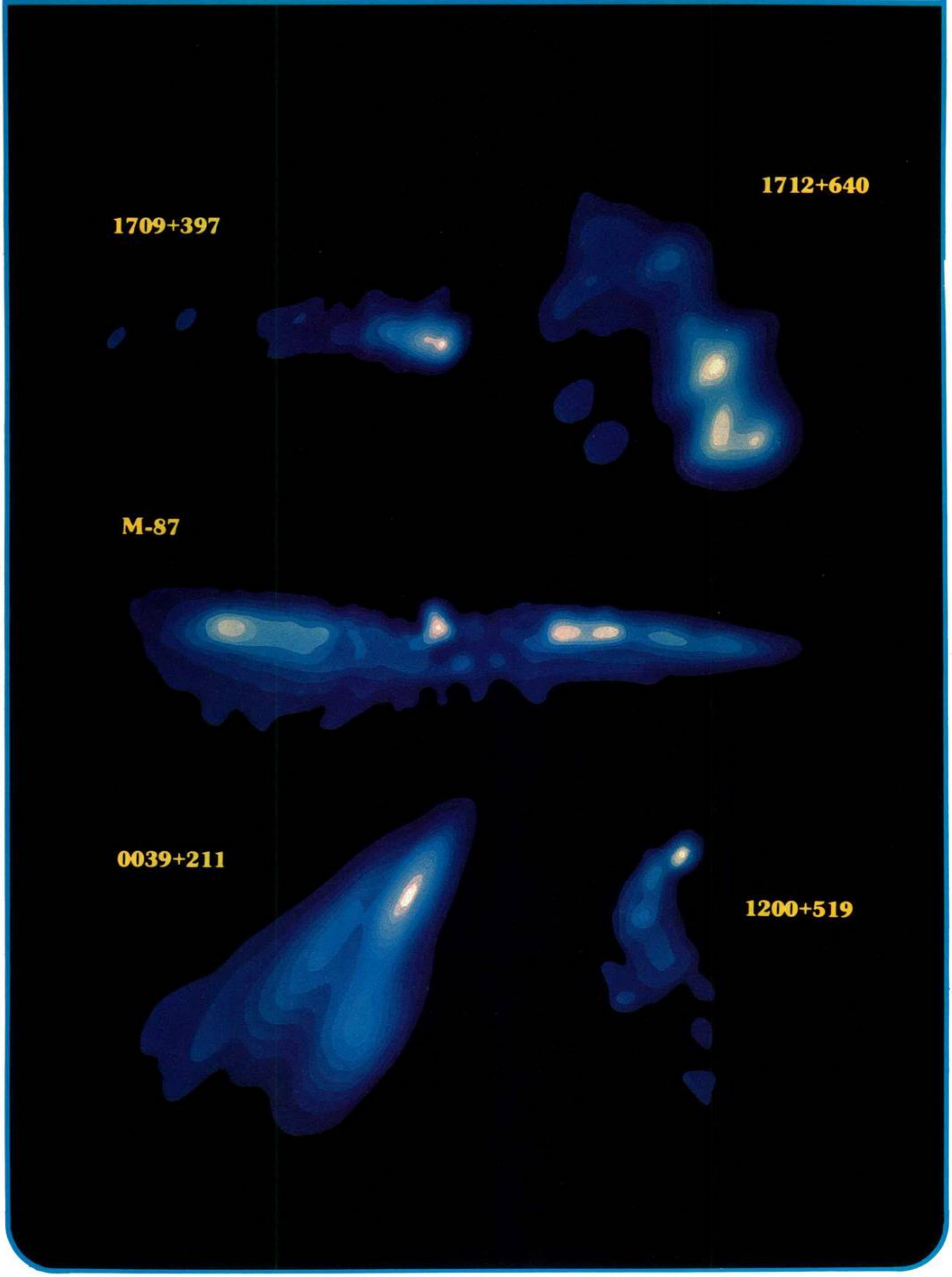
The rest, optical through gamma-ray frequencies, comes from another process called *Compton scattering*. Many of those infrared photons, smashing their way outward from the central source, will collide with the cosmic ray electrons and get reflected or *scattered*. Because the cosmic rays are energetic and moving at nearly the speed of light, most of the scattered infrared photons are given a tremendous blueshift, multiplying their freqencies by hundreds or thousands of times. Such violent scattering can upgrade an infrared photon into an X-ray one.

The Quasar Cookbook

Where do the cosmic rays and magnetic fields come from? There isn't any wholly satisfactory answer to this question, but astronomers are pretty certain they're there because of the electromagnetic radiation they emit. Today, two ideas seem at least plausible. One proposes that some central powerhouse throws off fast-moving jets of gas. Where these jets collide with the surrounding gas, the resulting turbulence might produce both magnetic fields and the cosmic rays.

The other suggests that quasars may contain a massive spinning object such as a rotating giant star or an accretion disk of gas spiraling into a black hole. The magnetic fields attached to this material would rotate,

The Structure of Quasars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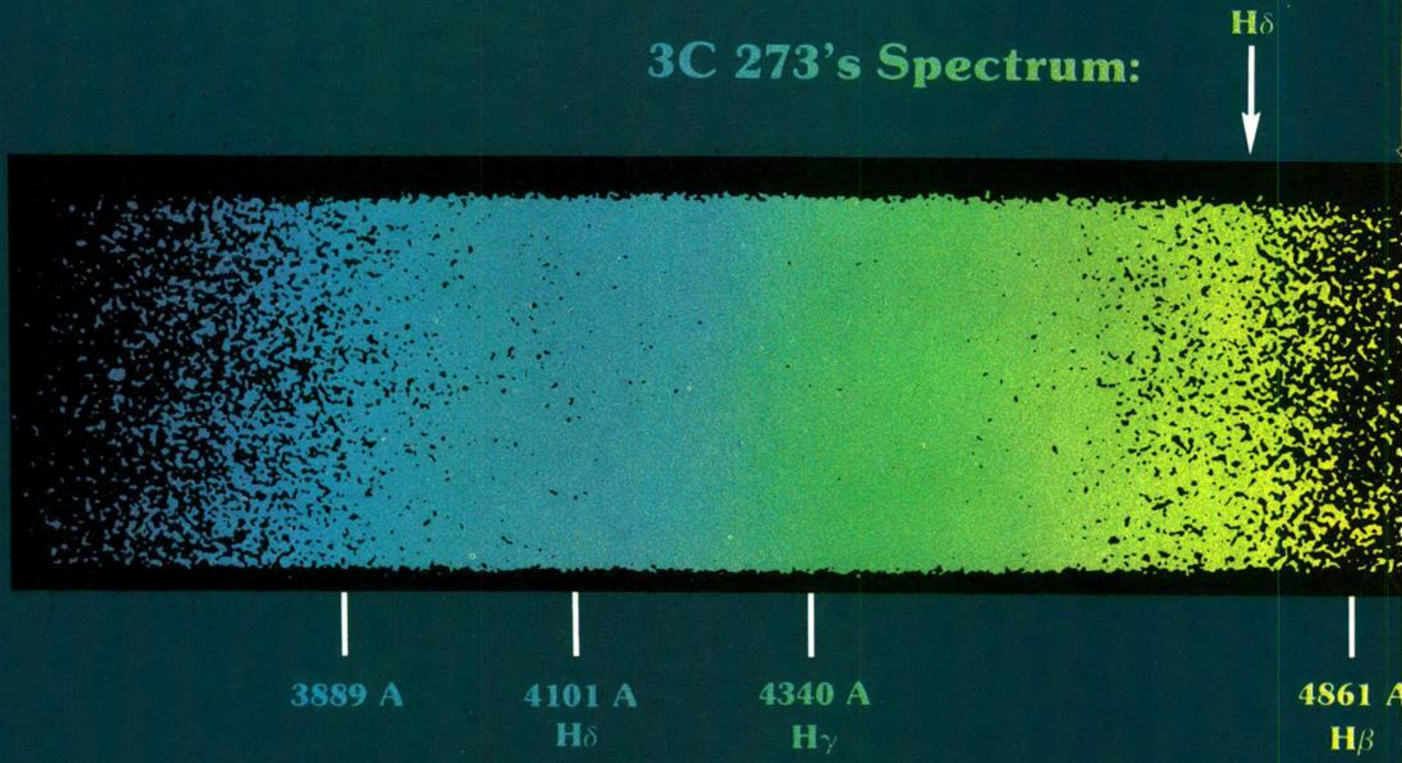


3C 273's Spectrum:

The Rule of the Redshift

Astronomers determine redshifts by comparing the wavelengths of elements seen in the object's spectrum with those calibrated at rest in the laboratory. Above, you see how three spectral lines of the Balmer series of hydrogen (Hβ, Hγ, and Hδ) have been shifted redward. The numerical value of the redshift, designated by the letter z, is computed by the formula:

$$z = \Delta\lambda/\lambda$$

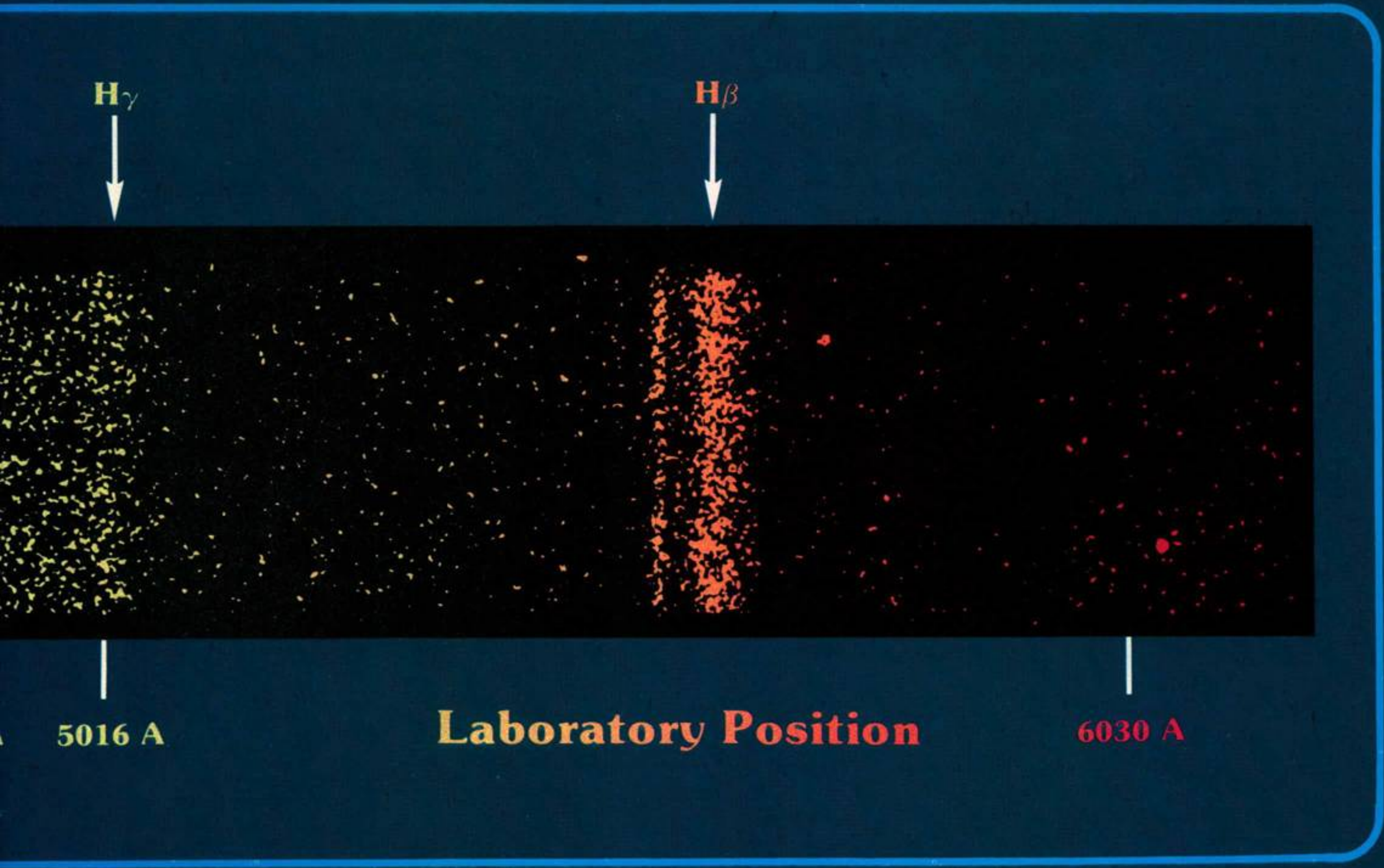
where λ stands for the laboratory wavelength and $\Delta\lambda$ the change in that wavelength. Velocity then is computed by: $V = cz$, or the redshift times the speed of light.

Try working out the z of 3C 273 for yourself! The lab wavelengths for Hβ, Hγ, and Hδ are 4861 A, 4340 A, and 4101 A, respectively, and the dispersion of the spectrum shown is about 7.2 A per millimeter. Work out the z for each of the three spectral lines and take an average.

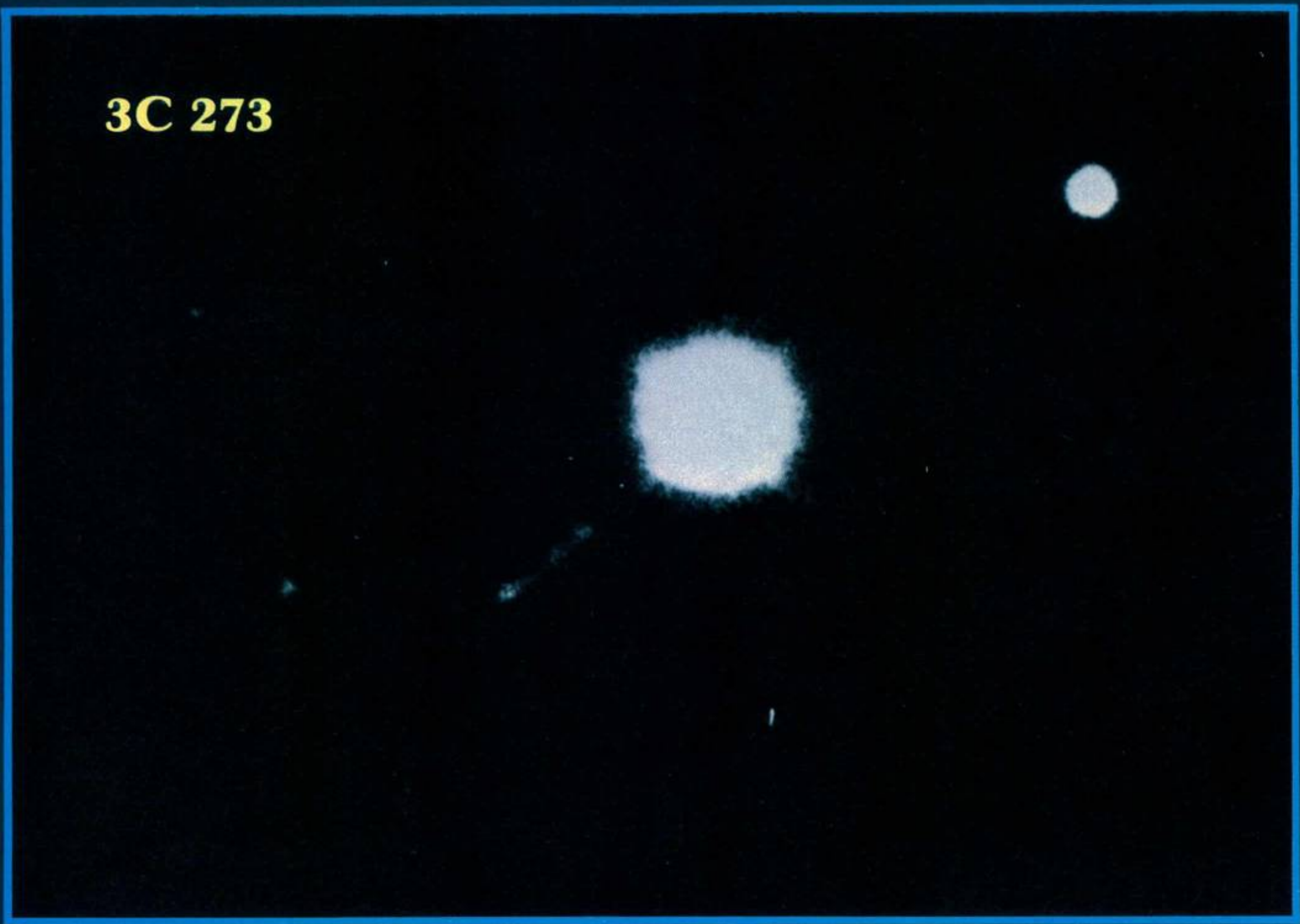
The formula above works well for low velocities (z less than about 0.3), but as velocities grow, relativity starts to have an appreciable effect. For example, a z of 1.0 implies a velocity equal to that of light. Accordingly, the expression for V must be modified to become:

$$V = c\,[(z^2 + 2z)/(z^2 + 2z + 2)]$$

Velocities derived with this formula, no matter how large the z, will come out less than c, the speed of light.

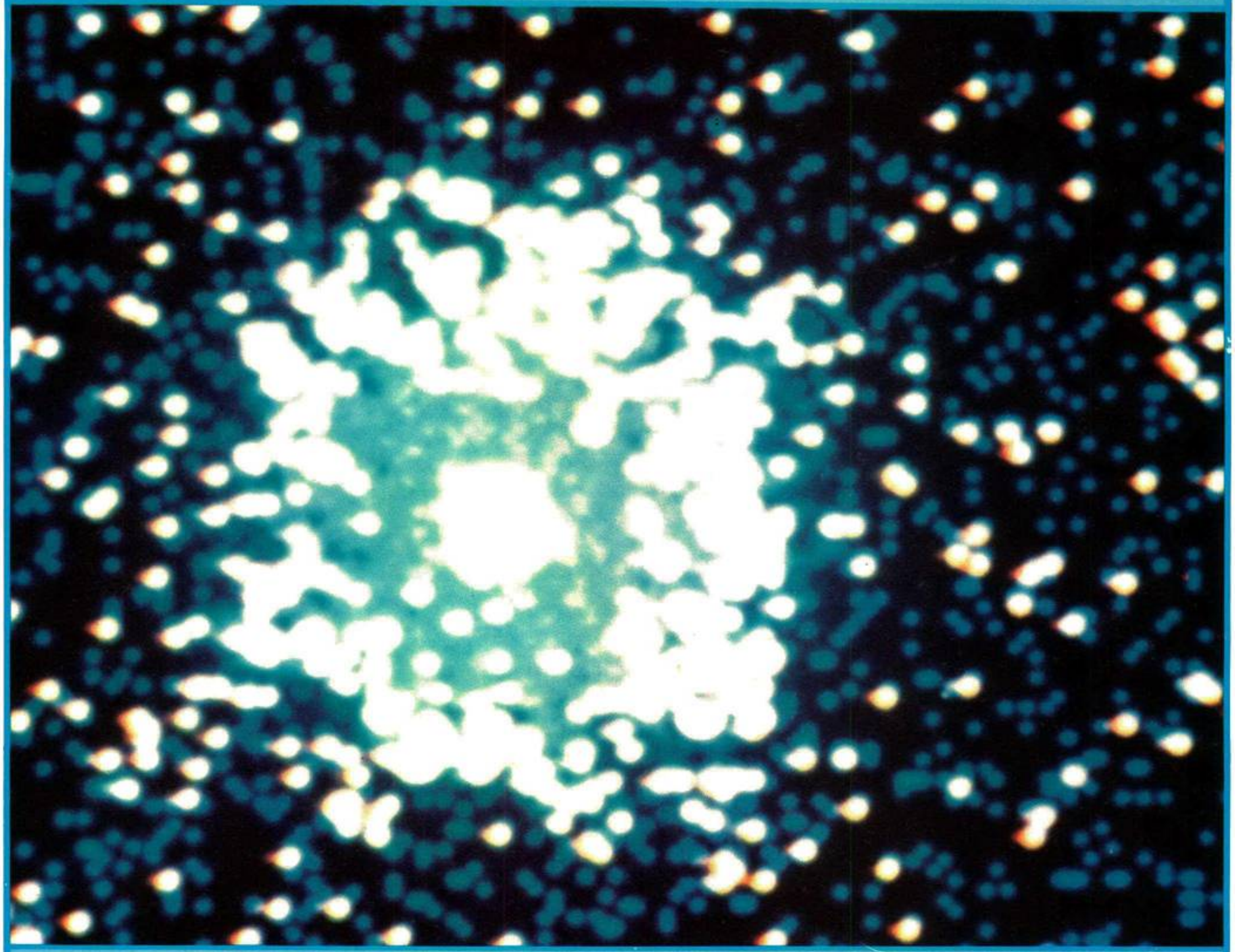


Hale Observatories



Kitt Peak National Observatory

The Biggest and the Brightest...



Largest Redshift: OQ 172

$Z = 3.53$: receding at 91% light-speed
8.8 billion light-years distant

Biggest: B2 1425+26 (??)

A radio source some 6.5 million light-years long

Brightest (apparent): 3C 273

$m_V = 13$ (approximately)
(3C 279 was at 11th magnitude in 1937)

Most Variable: 3C 279

Has varied over a range of 7 magnitudes, a factor of some 630 times

Smallest Redshift: 0241+622

$Z = 0.044$: receding at 4% light-speed
420 million light-years distant

Smallest: 0241+622

The core source is only about 2 light-years across

Fastest Expansion: 3C 279

Appears to be expanding at 10 times light-speed

Most Luminous: 3C 279 & 2134+004

$M_B = -31$ (approximately)
This makes both about 2,000 times brighter than the brightest galaxies

N.B.: These attributions are highly tentative and most will likely be revised in the future!

Appropriately enough for a table listing outstanding quasars, we seen an X-ray "photo" of 3C 273 taken by the Einstein astronomy satellite. Not only the brightest of all the quasars, 3C 273 was also the first to have the mystery of its anomalous spectrum solved. What at first looked like a weird mix of the totally unknown turned out to be ordinary elements weirdly displaced! Photo courtesy of SAO/NASA.

making cosmic dynamos to generate immense voltages. These in turn could accelerate electrons and protons up to cosmic ray energies, and additionally, power the jets beamed out at right angles to the accretion disk.

The optical and ultraviolet spectra of quasars show emission lines from hot ionized gas, lying typically a few light-years from the center of the quasar. Naturally, the gas becomes heated as the ultraviolet and X-ray radiation streams through. Cosmic rays and violent collisions of moving clouds of gas may well add to the uproar.

Evidence for violent action comes from emission lines in quasar spectra. Because they are broad, instead of sharp and distinct, astronomers think that their light comes from many gas clouds moving at speeds of up to 10,000 kilometers per second relative to the center of the quasar. Since some of the clouds' light is redshifted, and some is blueshifted (with respect to the quasar itself), the result is exactly the broad feature we see. As a best guess, astrophysicists suppose that some force, perhaps radiation pressure, is driving the gas clouds away from the energy source.

By studying quasar emission lines, astronomers hope to find out about the chemical composition of quasar material just as the composition of stars is inferred from their spectra. Their first results suggest that quasars arise from the same mixture of chemical elements normally present in galactic nuclei, adding weight to the idea that quasars and galaxies are members of the same family.

The Energy Crisis

But what lies in the center of a quasar? What ultimately powers all the activity? Quasars are so remote the answers remain obscure, but observation still can rule out many half-baked theories. Well, what observations does a theory have to fit?

Considering the size of the radio lobes, a typical quasar must shine for many millions of years. For the sake of argument, let's assume that a quasar can extract energy from its fuel pretty efficiently. The theoretical maximum energy, achieved by the total annihilation of matter, is given by Einstein's famous equation $E = mc^2$; let's assume the quasar can manage a conversion of 1/10 that. But then the numbers work out such that over its supposed lifetime, a quasar must consume a substantial fraction of all the mass in a galactic nucleus.

Obviously even less efficient processes, such as nuclear and chemical energy, can be ruled out; they require more mass than is available. The processes that appear efficient enough include matter-antimatter annihilation and gravitational energy. Because we have no evidence for significant amounts of antimatter in the visible universe, most present astronomers guess that quasars run on gravitational energy. Extracting gravitational energy from matter basically involves a supermassive star or a giant black hole. Black hole models are especially popular right now since the masses called for are so great as to leave few other options.

In a galactic nucleus, gas from dying stars might go into orbit around a black hole to form a flattened accretion disk somewhat resembling Saturn's rings. Friction in the disk would cause the gas to spiral into the black hole, generating heat and immense floods of radiation in the process. A lot of astronomers are busily engaged in the search for evidence to confirm or rule out this theory.

One clue lies in the suspiciously quasar-like behavior that occurs in the nuclei of some nearby galaxies called Seyfert galaxies. But Seyferts are pretty tame. Still, astronomers hope that quasars are essentially brilliant Seyfert nuclei, so that Seyferts, then, can provide a bridge to the distant quasars.

Perspectives on the Universe

Because quasars are so bright, we can see them from distances of many billions of light-years. The light from distant ones has been en route to Earth for billions of years — a large fraction of the age of the universe. In this way quasars give us an opportunity to probe the structure and history of the universe.

Quasars give us a look into the past. In the realm of space near us, there are only a few quasars. When we look far away, we look into the past because the light has traveled so long to reach us. Apparently, there were many more quasars when the universe was younger, 5 to 10 billion years ago, than there are today. Were all galaxies once quasars? We don't know.

You can get another perspective on quasar distances by using a result from the Big Bang model of the universe. As the universe expands, widely separated galaxies move farther and farther apart, i.e., the "scale" of the universe increases as it expands. It turns out that for a quasar of redshift 3.5 (receding at 91% the speed of light), the scale of the universe today is four and a half times larger than it was when the quasar emitted the light we see from it.

Studying quasars may help to answer the important questions of whether the universe will expand forever to re-contract, and whether it has infinite or finite extent. If the universe contains sufficient matter, its gravitational self-attraction will slow its present expansion to a halt; a contraction would follow that might end only when everything crushes out of existence in a fiery implosion.

Observing distant quasars may eventually allow us to compare the expansion rate of the universe billions of years ago with the present rate. Today, this cosmic crystal ball is only a hope; modern instruments and theories leave too many uncertainties for reliable measurement. However, as the story unfolds and our understanding of quasars improves, an answer may yet be found.

David Shaffer is a radio astronomer working with NASA's Very Long Baseline Interferometry group. His research interests are in the structure and evolution of compact radio sources. Greg Shields is associate professor of astronomy at the University of Texas at Austin; his research interests include emission lines and energy sources for quasars and the chemical composition of galaxies and nebulae.

Voyager Encounters

Saturn
Saturn
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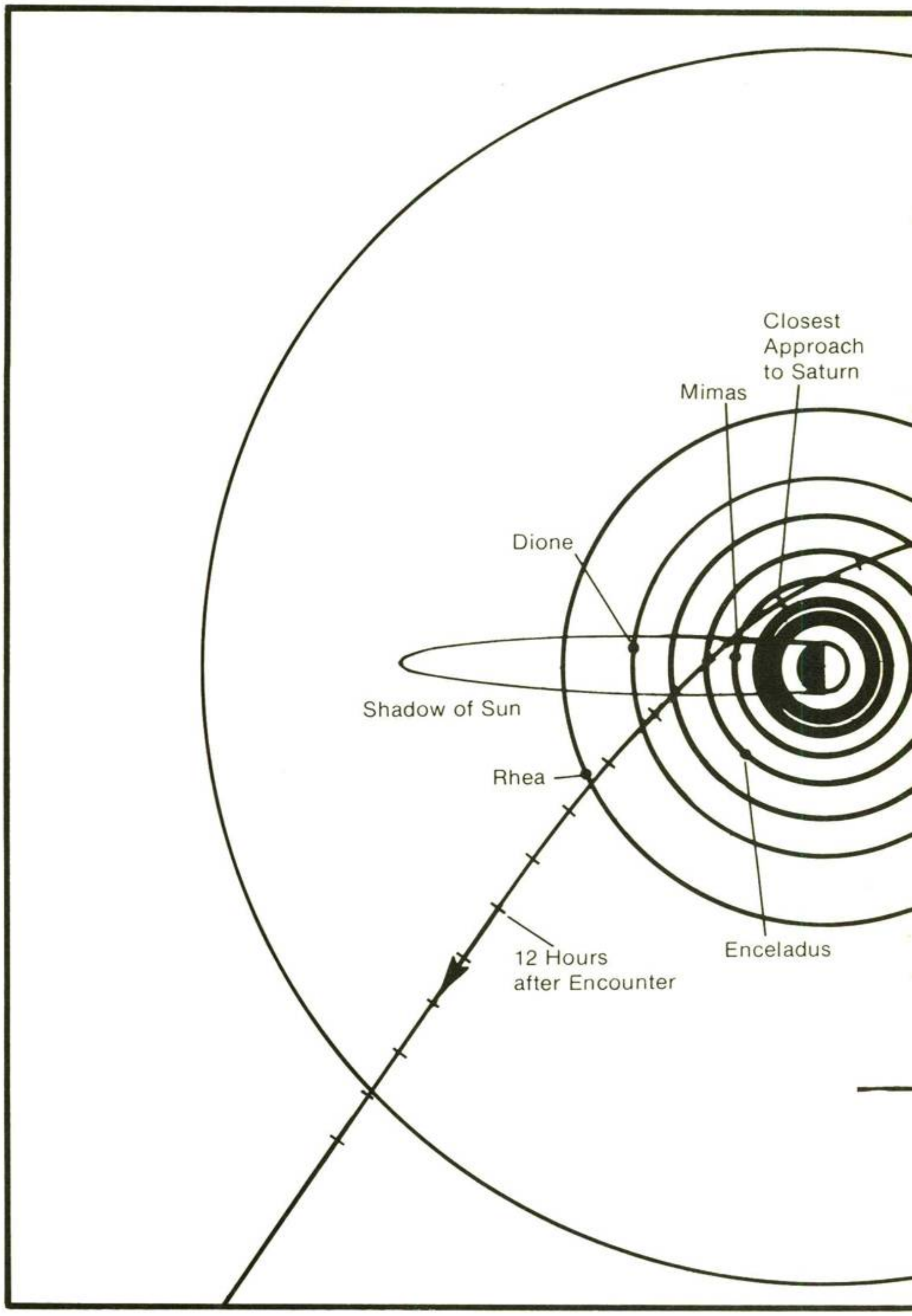
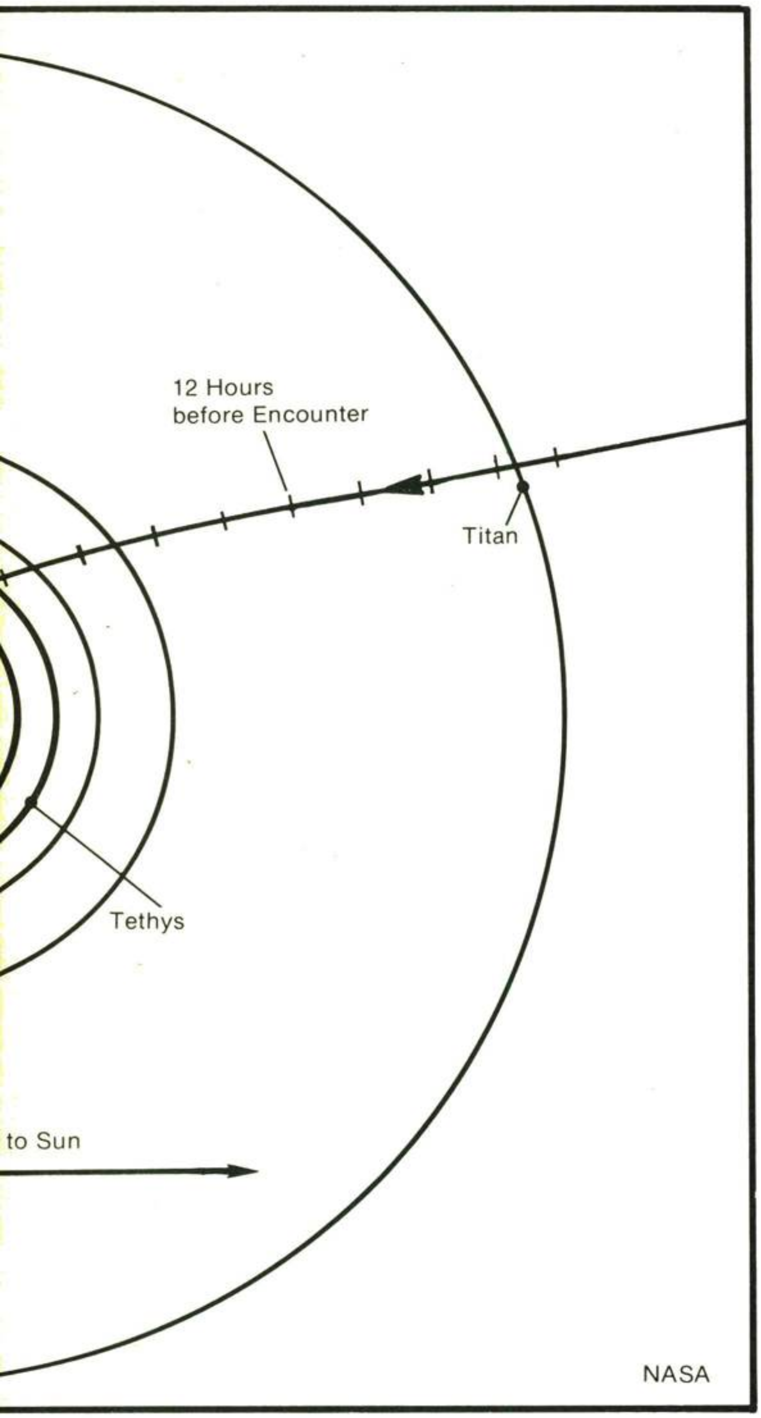


On November 12, 1980, the Voyager 1 spacecraft will reach the culmination of its 3¼-year-long voyage through space. As it swings past Saturn's great satellite Titan and then, a mere 18 hours later, whirls on around the great bulk of the solar system's second largest planet, its cameras, heat sensors, atomic particle and magnetic field detectors will photograph, measure, and sense the planet, its moons, and the fields and particles surrounding them. This phase of the craft's mission — controlled by complex sequences of computer commands radioed to the spacecraft 85 light-minutes away by the teams of scientists and engineers at the Jet Propulsion Laboratories in Pasadena, California — is its last destination. After the Saturn system, there is only the emptiness of space.

The highly automated Voyager spacecraft faces complex problems in its flight to the outermost planet of antiquity. Isolated by the great distance, the nearly three-hour communications gap imposed by the enormous gulf between the machine and its earthbound controllers, and the long duration of the mission, the Voyagers must be independent and able, to a large degree, to take care of themselves as they perform their detailed scientific surveys. Locked into its computer "brain," the spacecraft carries all the commands for a complete, though rather minimal, mission should its prime and backup radio receivers fail. Cut off from Earth, the craft would still perform its assigned tasks and radio the results back to Earth.

But if all goes well, Voyager will perform far more than a minimal mission. Twelve times before and



immediately after the encounter with Titan and Saturn, the giant 210-foot antennas of the Deep Space Network will broadcast — with 400,000 watt bursts of radio power — long strings of commands to the spacecraft. Received by the 12-foot dish of the Voyager, translated back into digital language, and loaded into its computer memory, will be the instructions for a comprehensive and meticulously detailed scientific encounter with the giant planet.

The basic spacecraft structure is a 10-sided aluminum framework nearly six feet across and 18 inches high. On this frame are the 10 carefully packaged electronics assemblies that make up the brains, the interpreters, and the radio voice of the spacecraft. The large radio dish that serves both the transmitters and receivers is 12 feet across, a paraboloidal dish of honeycomb aluminum that points, almost always, back toward its place of origin, the Earth.

The Voyagers, flying deep into space, cannot rely on solar power. Power is supplied by three radioisotope thermoelectric generators. Because of their radioactivity, they are hinged away from the delicate cameras and electronics on a lightweight boom structure. Many of the crucial science instruments — at the end of another boom 7½ feet long so that they are clear of mechanical and electrical interference from the spacecraft — are mounted on a two-axis scan platform which can be accurately pointed, by means of small motors, to virtually any angle relative to the spacecraft.

The twin television cameras, of course, are there, as are other remote sensing instruments. The infrared radiometer (a temperature sensor) and spectrometer (for measuring the composition of atmospheres), the ultraviolet spectrometer (which can detect atoms and ions in space around planets and satellites), and the photopolarimeter (which can determine, especially, what sizes and types of particles make up Saturn's ring) all ride on the scan platform and can be pointed at specific targets.

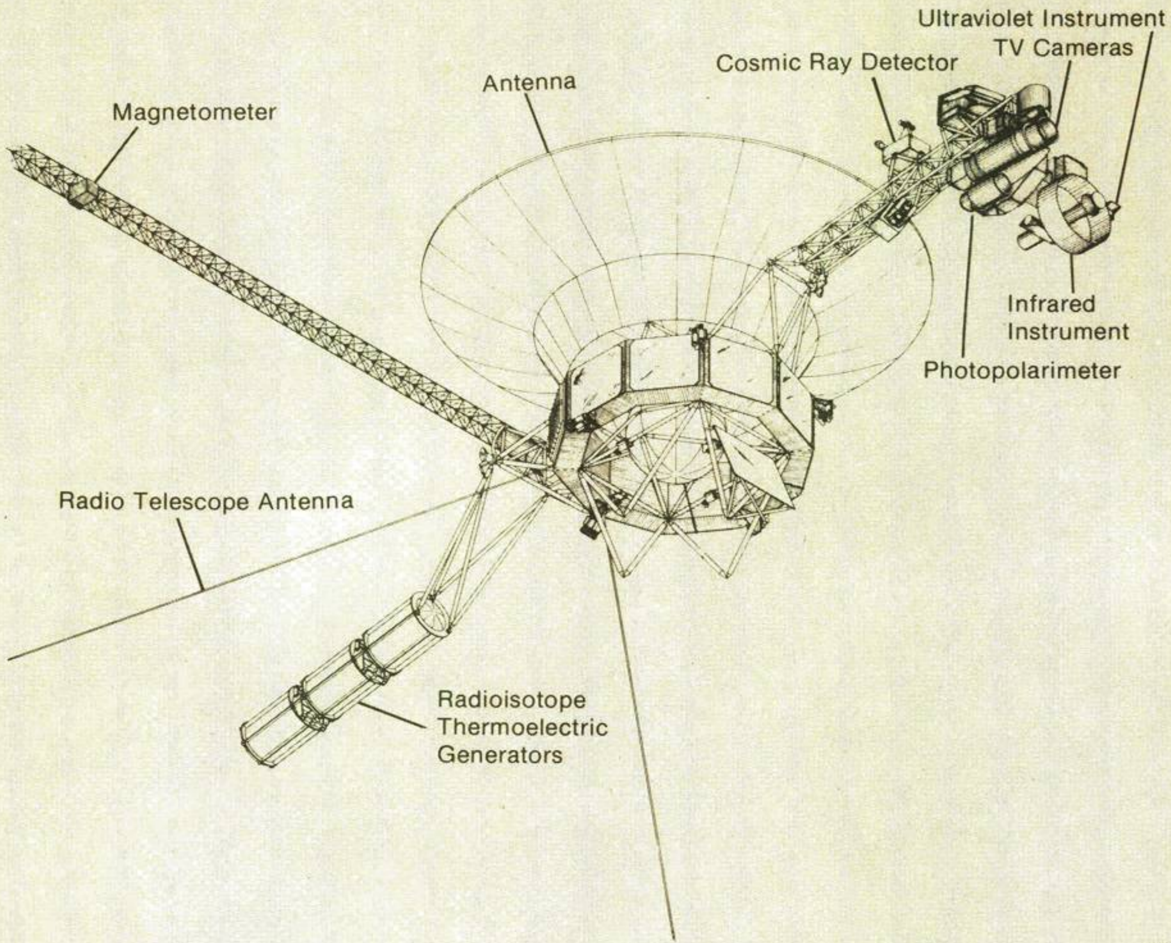
A typical set of commands in the computer's memory, for example, might start with the scan platform pointed at Saturn. After radioing 30 minutes worth of ultraviolet spectra for atmospheric composition studies, it might slew to the rings for a series of infrared heat measurements of the rings, then slew again to the spot where a particular satellite is, wait a minute for vibrations in the boom to die down, then shutter the cameras for 30 minutes in a pre-selected sequence of exposures through color filters.

The cameras are marvels of precision, miniaturized television systems attached to powerful telescopes. Each camera can be switched from a narrow-angle lens with a view of 0.424° to a "wide-angle" view of 3°. Their resolution, from one million miles away, is about five miles.

Saturn and its rings will be too big to fit in the narrow-angle camera's view 25 days before the encounter — from about 40,000,000 miles away. From Saturn, the rate at which pictures can be returned to Earth is limited — by the weakness of the radio signals after crossing a billion mile separation — to one full frame every 144 seconds. (From Jupiter, the same spacecraft could transmit a frame in 48 seconds.) To make color photographs, a camera is shuttered three times: once with a red, then a green, and a blue color filter in the imaging beam. After transmission to Earth, followed by digital cleanup and alignment in a large computer, the three filtered black and white images are finally reassembled on color film at JPL.

Other science instruments on board include a cosmic ray detector to investigate these high-energy particles from the Sun and our Galaxy, a low-energy charged particle detector to "weigh" the atomic particles trapped in Saturn's magnetosphere, a sensitive magnetometer to "feel" the magnetic fields in space and near planets, a "radio telescope" that uses two thin antennas to investigate bursts of radio power from Saturn and the particles in space around it, and detectors to "sniff" the clouds of ions that

Voyager



NASA

seem to fill the magnetospheres of the giant planets.

During the hectic phases around closest approach, when many of the science instruments are operating at the same time (producing too much data to transmit back to Earth), an on-board tape recorder can store, for replay, data equivalent to about 100 pictures. This allows the infrared instrument to operate while the camera takes pictures, or allows the radio instruments and plasma wave detectors to accumulate data even when the spacecraft is transmitting back a continuous stream of picture data.

The Voyager 1 mission is divided into a number of distinct phases of activity as it approaches the ringed planet. Though closest approach to Saturn occurs on November 12, much of the important science activity will occur in the days and weeks before and after encounter. The mission phases are consonant with the abilities of the cameras, remote sensing instruments, and fields and particles detectors.

The first phase of the mission — the Observatory Phase — began on August 22 and lasts until October 20. Science activity, leisurely at first, begins to build up as Saturn comes within range of the instruments. Engineering and instrument calibrations occupy much of the time, as the infrared and ultraviolet sensors are pointed at the cold and blackness and the warmth and light of the Sun. Saturn is studied for its overall brightness in infrared and ultraviolet, and twice daily its radio emissions are sensed.

During the observatory phase, long-term monitoring of Saturn's atmospheric circulation takes on great importance. "Zoom movie" sequences, made up from hundreds of frames taken every two hours three minutes apart, will permit time-lapse studies of the belts and zones in the clouds. Sixty-one days before encounter, the cameras will begin a continuous 102½-hour coverage following 10 complete rotations of Saturn for the Public Information Office. This time-lapse movie, to be shown on television, will show Saturn spinning majestically on its axis.

Thirty-three days before encounter, the cameras will begin daily coverage of Titan, Saturn's largest satellite. At first the image will be tiny, filling only 1/60 of the television frame, but it will grow 50% larger by 20 days (-20 days) before encounter.

The Far Encounter 1 Phase will begin on October 24, at -19 days, with the Voyager Mission claiming the full use of the biggest and most sensitive antennas in NASA's Deep Space Network. The pace will now begin to increase because data can be transferred from Voyager at higher rates, and because Saturn is

getting closer and closer.

Eleven times each day, two full-color pictures will be taken of Saturn's globe. (The ring no longer fits into the narrow-angle camera frame.) At the same time the pictures are taken, the infrared instrument will measure the heat and composition of the planet. A global movie, scheduled for October 17 (-26 days), will show the disk of Saturn filling the frame through two complete rotations. The ultraviolet scans of Saturn will be stepped up also, to seven ultraviolet mosaics per day. Meanwhile the steadily-growing image of Titan will be monitored with five narrow-angle pictures four times each day. Plasma wave observations (fluctuations carried through the soup of ions and electrons around Saturn) will be added to a growing repertoire of fields and particles studies.

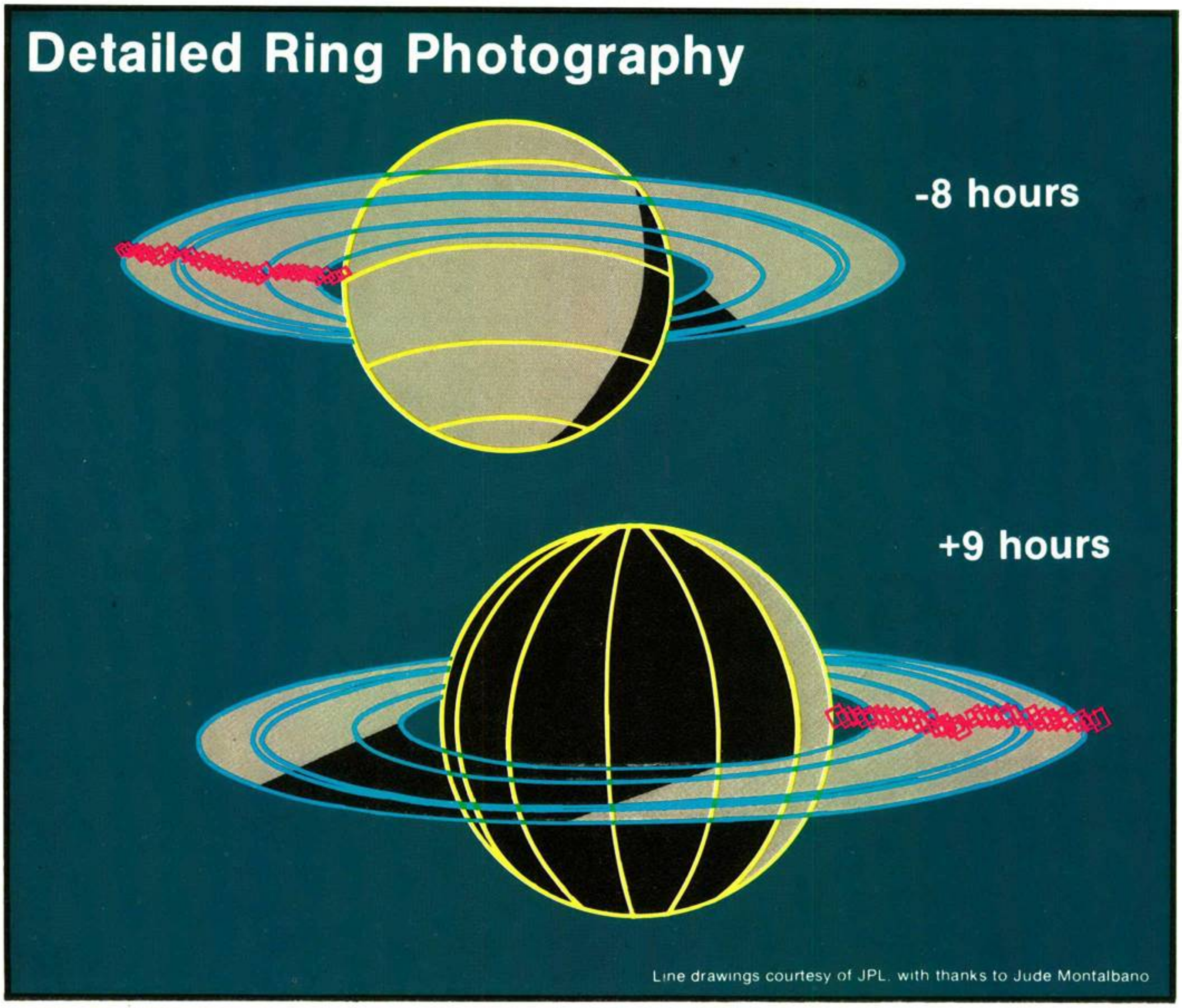
Far Encounter 2 Phase begins nine days before the flyby with a new load of commands for the on-board computer. As Saturn fills a larger and larger portion of the spacecraft's sky, detailed imaging and infrared remote sensing mosaics and ultraviolet scans (stored on the tape recorder for convenient replay) grow in importance. Ultraviolet measures of Enceladus, Rhea, Tethys, Dione, and Mimas begin.

From day -9 through day -6, the planetary radio emissions of Saturn are measured once a day, but high resolution color mosaics are the main business for Voyager. Besides the 11 daily monitor pictures, a "super" series of the best high resolution pictures that will be obtained during the mission are taken once each day. Each such "super shot" requires 15 exposures to cover the planets and rings through each of three color filters — a sizeable investment of time and data transmission capability. Four times each day, five narrow-angle images will add to the growing coverage of Titan's probably cloud-covered surface.

From the sixth to the fourth days, another new set of commands will instruct Voyager to raise the rates still higher. With Titan filling a sizeable fraction of a narrow-angle frame, it will be recorded six times a day. Mosaics of Saturn itself, with piggybacked remote sensing, are now made nearly every time the scan platform is pointed toward the planet.

As encounter draws nearer and nearer, the emphasis will shift to the remote-sensing instruments. Nearly all of the third and second pre-encounter days are devoted to three extensive infrared "temperature and composition" measurements that will blanket the planet's disk, interrupted only by extremely detailed narrow-angle pictures of the Saturn clouds.

Immersed in the magnetosphere of the planet since the sixth day before close approach, the particle



Line drawings courtesy of JPL, with thanks to Jude Montalbano

and magnetic field instruments will have been returning reams of data about the magnetic field and the ions and atoms that move within the magnetosphere of a planet both curiously like and unlike the giant Jupiter. Thirty-four hours before closest approach to Saturn, and 16 hours before closest approach to Titan, Titan will at last fill the frame of the narrow-angle camera.

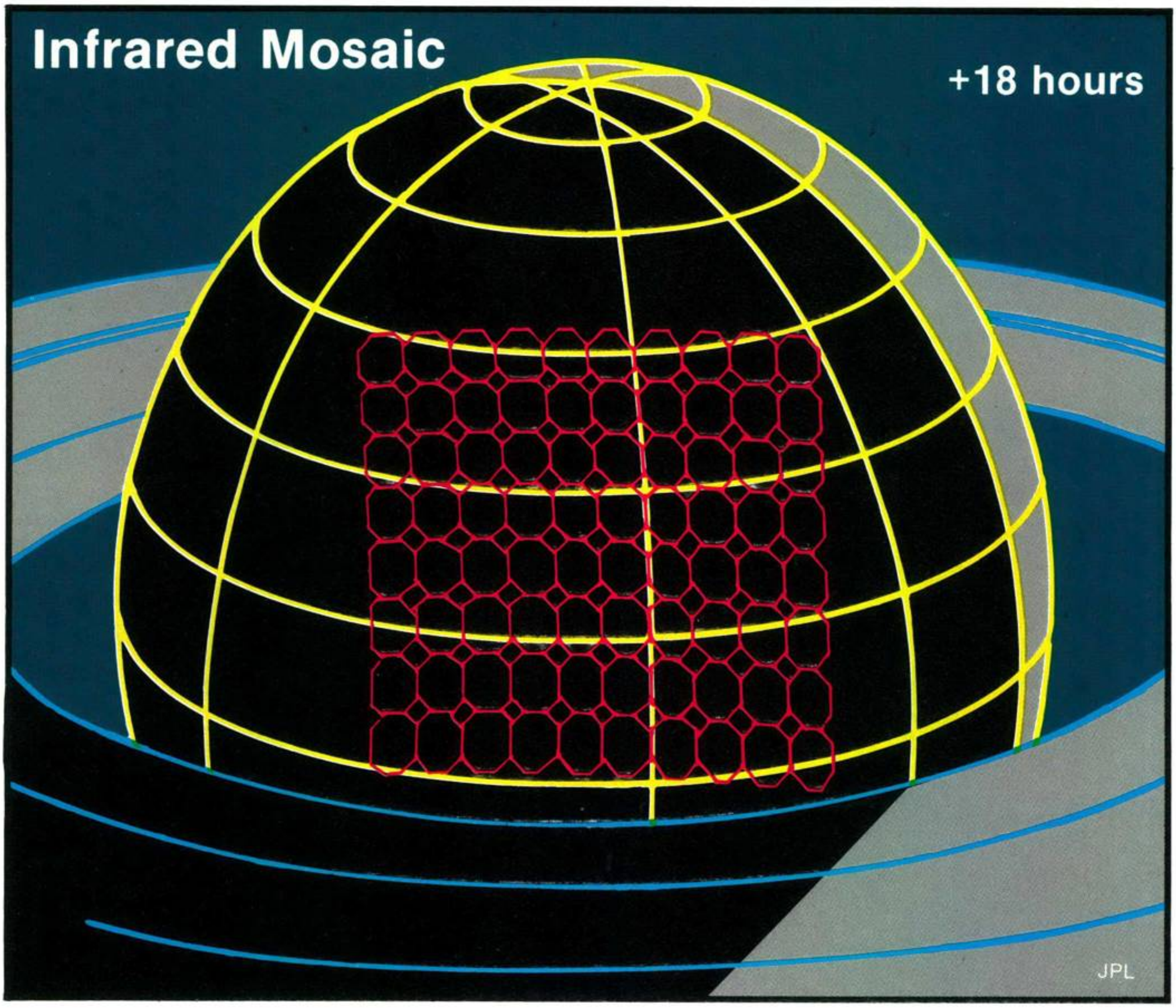
Twenty-six hours out, the Titan Encounter Period begins. Over 60% of the data taken for the 12 hours of Titan close approach will be Titan data. Detailed pictures of Titan will begin with two hours devoted to a nine-image mosaic picture through each of four color filters. Next will come a group of six images of Dione, six of Enceladus, 30 minutes of Titan ultraviolet data, and then, as time becomes too short to radio the pictures back in "real time," a 20-image mosaic of Titan will be shuttered and stored on tape for later replay. After another half-hour-long ultraviolet observation of Titan's bright limb, the cameras will swing back to Titan. Beginning only 11 minutes before closest approach, the cameras will take a set of 13 very high-resolution images.

As the spacecraft approaches Titan's sunlit side and flies past the southern polar regions of the satellite at a range of about 7000 kilometers on November 11, the time will be 9:37 p.m. in California and just after midnight on the East Coast. Five minutes later, Voyager will fly into Titan's shadow. Then a bit over a minute after that, communications will cease as the craft disappears behind Titan.

Ten minutes later, communication should be restored. Radio signals, passing through Titan's atmosphere just before and after the occultation, and the ultraviolet light from the Sun will be carefully monitored as they are attenuated by Titan's atmosphere. The yield will be data on its composition, depth, and pressure.

While still in Titan's shadow, another significant event will occur: Voyager, previously flying on the northern side of the ring plane (the side of the rings the Sun will also be shining on), will pass to the southern side of the ring plane. Until 4½ hours after the encounter, the craft will be on the dark side of the rings — the side recorded by Pioneer 10 in 1979.

The Near Encounter Phase will begin just 14 hours before Voyager (at a distance of 185,000 km) makes its closest approach to Saturn. In this phase, the fields and particles instruments will be hard at work. Important information will be gleaned from the



occultation of Voyager's radio signals as it flies behind Saturn about an hour after closest approach, and again when it emerges from behind the planet and then transmits, for about 15 minutes, through the rings.

Voyager will also pass closest to five of Saturn's satellites during this phase. Mimas will fill, at best, about one-half a narrow-angle camera frame. Before closest approach, Enceladus will only fill one-tenth of a frame, but Tethys, half-illuminated, will fill one-fourth of a frame, and rate nearly a dozen exposures. Dione will merit an overlapping mosaic of seven narrow-angle frames.

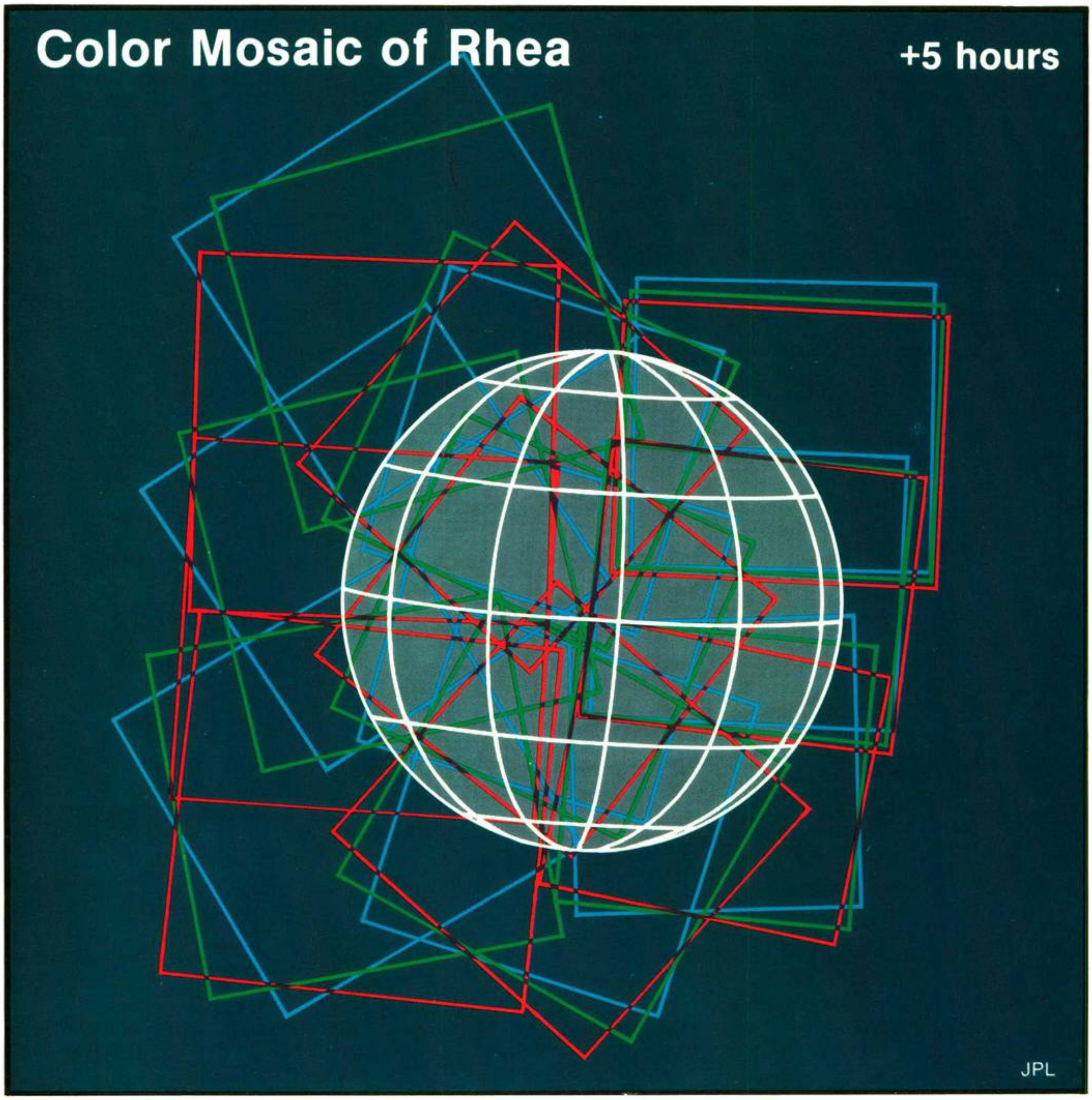
After closest approach — when Voyager is closest to it — Enceladus, appearing as a thin crescent, will fill one-third of a frame and rate over a dozen exposures. Hyperion and Iapetus, both more distant, will be tiny even in the narrow-angle frames.

Rhea, which goes into eclipse behind Saturn just a few hours before closest encounter, will be observed with the infrared radiometer to see how it cools, and again when it exits Saturn's shadow to see how its surface heats. Some five hours after encounter, Rhea will be examined in greater detail by the cameras: 27 narrow-angle frames will make a color mosaic (see page 22) and 15 high-resolution unfiltered mosaic images will be shuttered.

The infrared and ultraviolet instruments will be especially busy as they blanket the globe and rings of Saturn, look at the poles for aurorae, at the backside of the planet for lightning, and at the satellites for traces of atmospheres. The rings will be thoroughly observed: their temperature in sunlight and shadow, the speed at which the rings cool when they orbit into the shadow, will all contribute to an understanding of what the rings are made of.

Besides photographing, in turn, each of the satellites, the Voyager cameras will also explore the structure of the rings. The Sun will be shining on their northern side as the spacecraft swings past the planet moving farther and farther south. A trail of high resolution images across the rings, eight hours before encounter, will provide in detail never seen before, information on the structure, brightness, and particles that make up the ring. (See page 20.)

Seventeen hours later, after Voyage has recrossed the ring plane and is on the sunlit side, another sequence of images will be made to complement the first. This set of high resolution images will show the Encke's and Cassini's divisions.



Wide-angle frames will detail the entire ring system from the dark side, and later exposures will probe the shadow of the ring on the planet. Still another sequence at the time of ring plane crossing will be made to search for faint extensions of the main rings, and yet another will look back on the D-ring (a ring very close to the planet's surface) to see if it can be seen better from behind, as Jupiter's ring was.

After Near Encounter comes the Post Encounter Phase lasting until +36 days. The pace of observation and, with it, the flow of data slow. The full Deep Space Network will no longer follow Voyager after day +10.

From the spacecraft, an approximately half-illuminated Saturn will be observed from an angle never seen from Earth, and the cameras will resume the regular pattern of daily photographs for "zoom" movies and cloud motion studies. A search for previously unseen satellites between Mimas and the rings will be carried out, as will a systematic study of the narrow crescent of Titan. All told, the cameras will be kept busy imaging almost continuously about 14 hours per day.

The remote-sensing instruments will continue measuring the planet and the ring, searching for a Io-like hydrogen torus of material in Titan's orbit, and looking for aurorae on Saturn. The cameras will make a number of special mosaics of Saturn. One, taking nearly eight hours to shutter and radio back to Earth, will contain 161 individual images of the planet's gibbous phase.

Voyager 1 will be a live and communicating spacecraft for as many as 10 years after it leaves Saturn. Its path, most unfortunately, cannot be altered to send it on toward any other planets, so *it will glide for millions of years more away from our Sun, out into* galactic space. — *Richard Berry*

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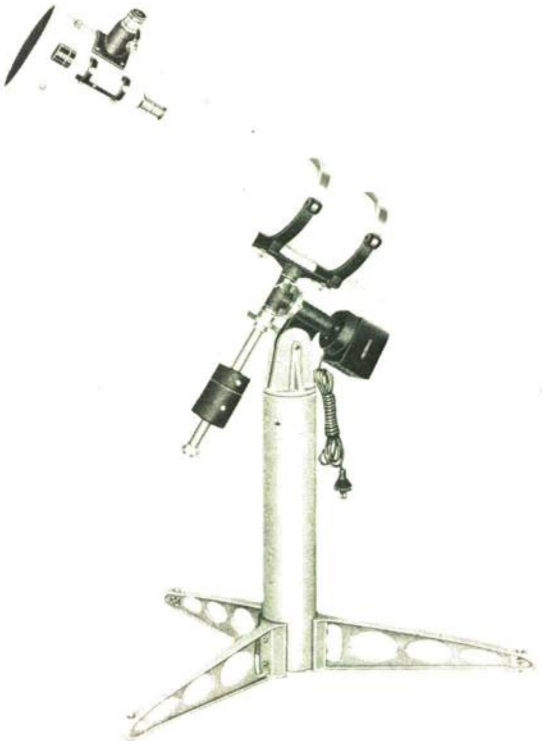

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ASTRONOMY FORUM

Encounters with Yuri Alexeyevich Gagarin

We had absolutely nothing in common. He was a Soviet citizen and I an American. He did not speak English; I did not speak Russian. We lived on opposite sides of the world, yet we had two encounters.

I will never forget the first time I saw Yuri. It was soon after sunset on a golden California evening. I was on the way back from waterskiing on the Salton Sea and was driving west on U.S. Highway 10 with my wife and two boys. I had turned on the radio early to make quite sure that I would see him at the appointed hour. He would be right on time.

I stopped the car on the north side of the freeway just past the large eucalyptus trees which had been planted as windbreaks long ago. I did not want them to block my view of him when he arrived. A nearby sign read "Sierra Blvd., Fontana."

The sky was deep purple. I started looking up at it the moment I stepped out of the car. It got dark fast, and I had just begun to worry that I might miss him. But his approach was arrow-straight, and not quite overhead. Rather to the north, I seem to recollect.

I remember telling the boys, Quinn and Shawn, that there was a man, a citizen of this planet, in the tiny capsule way up there in space. A human was circumnavigating our Earth, his sheltering craft yet illuminated by sunlight long after the Sun had set.

This was high adventure. The first man in space, hurtling through a hostile vacuum environment, navigating previously uncharted paths. A 108-minute single orbit around the planet Earth, launching man's dreams of escape from gravity and vaulting a previously unknown Russian airman into immortality. It was April 12, 1961.

Our next encounter was not until twelve years later. This time it was on Yuri Gagarin's homeground. While in the Soviet Union, during a visit to Moscow, we had gone in search of the notorious Stalin's grave along the cemetary brick wall surrounding the Kremlin. Suddenly I saw the unassuming marker. The immortal name was finely chiseled into stone: "Yuri Alexeyevich Gagarin," it read.

And then I remembered that first evening near Highway 10 in California.

We had absolutely nothing in common. He was a Soviet citizen, and I an American. He did not speak English; I did not speak Russian. We lived on opposite sides of the world — a mere thirty minutes apart....

Ben Mayer
Los Angeles, CA

Oberg in Confusion

The following is in response to James Oberg's "Predictions in Collision," in ASTRONOMY's Forum, July 1980.

James Oberg began his attack on Velikovsky with his one largely correct statement: "The true test of a new scientific model lies in its ability to make" (though he should have said "generate") "testable predictions which are at variance with expectations based on accepted models of the universe." That he proceeded to ignore this throughout the rest of his polemic is testimony not to Oberg's faulty memory, but to the fact that contrasting Velikovsky's "model" with the "accepted model"

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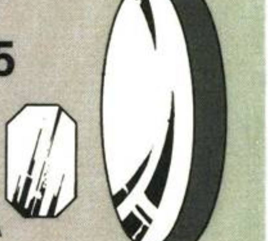

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of solar system history can only lead to conclusions favorable to Velikovsky.

Before going on, however, some important questions deserve consideration.

Is Oberg's analysis the "dispassionate consideration of the evidence" that he pretends? Consider the following: In the paragraph are quotes from Carl Sagan and his protege David Morrison. The arguments of both men have been rebutted on several occasions and in at least three different publications (articles in the Fall 1977 and Fall 1978 issues of *Kronos* entitled "Velikovsky and Establishment Science" and "Scientists Confront Scientists Who Confront Velikovsky," as well as *The Zetetic Scholar*, and "Velikovsky and his Critics" by Dr. Shane Mage). Oberg is most disingenuous not to acknowledge the true state of the dispute when quoting them against Velikovsky.

Is Oberg's "investigation" as slipshod as it is one-sided? Judge for yourself. Certainly he was wise to exclude ancient history from his analysis because he does not even know when the events in *Worlds in Collision* were supposed to have happened. Since Velikovsky dated the Exodus to about 1450 B.C., Oberg is quite off the mark talking about "manna" falling "to Earth in 3500 B.C. to nourish the Israelites."

Other examples of Oberg's slipshod manner include:

1) contrasting "ferric" with "ferrous" using the same ambiguous phrasing that was pointed out to him in correspondence with Fred Jueneman, an Associate Editor of *Kronos*;

2) identifying as "the then editor-in-chief" of *Kronos*, L.M. Greenberg, who is the present and only holder of that position (n.b., Oberg subscribes to *Kronos*); and,

3) insinuating that Velikovsky believed that "manna," a carbohydrate or protein-based substance, fell to Earth from Venus (Velikovsky attributed its origin to the conversion in Earth's atmosphere of hydrocarbons deposited there by Venus).

As an aside, the same Oberg who told *Kronos* he wished to "talk planets, not personalities," proceeds twice to identify the late Ralph Juergens as a "disciple." This is ridiculous: a disciple is not known, as Juergens was, for being interested in finding out "how," since faith covers all doubt.

Methodologically, Oberg's approach is slipshod because he did not "compare [Velikovsky's predictions] to space data," but to *interpretations* of space data. This distinction may appear trivial, but it is not. Scientists, and Mr. Oberg as well, operating within the confines of the "accepted model" (faith in which led certain professors of astronomy from Harvard's Shapley in 1950 through Sagan today into denouncing Velikovsky as an heretical "pop-science notable") base their thinking on three main premises:

1) that the solar system was formed in a single and uniform process;

2) that the present arrangement of its major components has endured for billions of years; and

3) that electricity and magnetism play no significant role in its dynamics.

Velikovsky in Overview

When *Worlds in Collision* was published by Macmillan in 1950, it became the focus of controversy. Astronomers, led by Harlow Shapley of Harvard, were outraged by the book and boycotted Macmillan's textbooks. Macmillan gave the book to Doubleday, a commercial publisher with no textbooks to be boycotted.

Worlds in Collision presents archaeological, historical, and mythological evidence showing that between 1450 B.C. and 687 B.C. the solar system was unstable and Earth was subjected to a number of near collisions, first with the young protoplanet Venus (then possessing a cometary tail and a highly eccentric orbit) and later Mars.

In Velikovsky's scenario, Venus originated some unspecified number of centuries before 1450 B.C. by expulsion from Jupiter's core as the result of an instability initiated even earlier by Saturn. During this earlier epoch, the orbits of both Jupiter and Saturn were different than today's.

According to Velikovsky, the world's ancient myths, folklore, and sacred literature constitute a collective memory of celestial disorder. These cataclysmic events, which deeply traumatized the human race, have come down to us today coded in religion and legend and as a subconscious compulsion to wage war in the name of higher authority. The process by which later generations interpreted explicit written descriptions of the catastrophes as metaphor and allegory was indicative of a "collective amnesia," the subject of Velikovsky's forthcoming book, *Mankind in Amnesia*. Geological and paleontological evidence for these events was assembled in Velikovsky's *Earth in Upheaval* (1955).

The Velikovskian reconstruction of ancient history between the 15th and 4th centuries B.C. requires a general lowering of Egyptian dates by at least 500 years. The starting point is the synchronization, which is not acknowledged by conventional reckoning, of the Hebrew Exodus with the end of the Middle Kingdom in Egypt about 1450 B.C. Velikovsky's revised chronology, it is claimed, can not only resolve historical enigmas, but produce salutory "fits" among Egyptian, Jewish, and other ancient eastern histories that are lacking in the accepted scheme.

The astronomical evidence supporting *Worlds in Collision* includes, for example, the 360 day calendar employed between the 14th and 7th centuries B.C., ancient clocks that do not "work" at the latitudes where they were found, and the "Venus Tablets of Ammizaduga."

C. Leroy Ellenberger

People, even scientists, often "see" what they are looking for. Furthermore, data lose their neutrality once they have been selected from a universe of stimuli. The objective viewpoint soon becomes colored, and facts not in accord with their premises are ignored.

Oberg states, for example: "Radioactive dating [of lunar samples] indicates that the last melting took place billions of years ago..." But radioisotope dating determines age, not thermal history. Regarding the time since the last melting, Velikovsky replied, in response to an earlier critic, "The question is not when the rocks have been formed or for the first time crystallized, but when they were heated and partly molten for the last time." Velikovsky then went on to cite the thermoluminescence study on Apollo 12 cores which indicated thermal disturbances in historical times.

A principal objection to Oberg's article is that he fails to distinguish between Velikovsky's incidental remarks and the essential predictions that can be derived from theory. The correctness of surmises such as the possibility of life on Mars, the amounts of argon and neon in the martian atmosphere, and the intensity of moonquakes, is inconsequential to the validity of Velikovsky's version of the recent history of the solar system. If what Velikovsky said happened, *really* happened, then certain things follow as logical deductions from the basic hypothesis.

But even if Oberg's treatment of Velikovsky's writings were less full of errors and misstatements than it is, his thesis would be sufficiently refuted by those facts which bear directly on the confrontation between the "accepted" and "heretical" models. Facts from three key areas will be reviewed: radio emissions from Jupiter and the Earth's magnetosphere; a recent large thermal event and formation of short-lived radioactive elements on the Moon; and the temperature and composition of Venus' atmosphere and an internal heat source on Venus.

Regarding Jupiter, Oberg's dismissal of Velikovsky's 1953 prediction of jovian radio noise is a *non sequitur* and falsification of the nature of the prediction. Oberg is flatly wrong when he says Velikovsky was wrong about Jupiter's temperature. Velikovsky was merely reporting the observation that the visible atmosphere is cold and in motion. Every school boy knows that terrestrial lightning is produced by the Earth's atmosphere in motion. Jupiter's high core temperature is not contradictory in context, as will become clear.

Oberg is also wrong, as was Carl Sagan before him, in stating that Velikovsky merely predicted thermal radio noise. In *Worlds in Collision*, Velikovsky discussed electrical discharges in Jupiter's atmosphere and called Jupiter "a dark star." In their December 21, 1962 letter in *Science*, Princeton physicist V. Bargmann and Columbia astronomer Lloyd Motz, in crediting Velikovsky with priority in predicting, among others, Jupiter's radio noise, remarked: "Radio astronomers had never expected a body as cold as Jupiter to emit radio waves."

Curiously, Sagan deleted the Bargmann/Motz credit from the published version of his 1974 AAAS talk.

But Jupiter's thermal emission is not the point of Velikovsky's prediction, but rather the unexpected electromagnetic similarity. The prediction was crucial because on it Velikovsky had staked the outcome of his informal debate with Albert Einstein concerning the role of electromagnetic interactions in the solar system.

"At some point in our debate [wrote Velikovsky, in a June 1954 letter], I offered to stake our debate on whether Jupiter sends out radio noises (of non-thermal nature, as I already claimed in my Forum Lecture of October 14, 1953), to which he reacted skeptically, yet was greatly surprised when nine days before his death I brought to him the news (*New York Times* of April 6, 1955) that such radio noises were accidentally detected." So struck was Einstein that he offered to use his influence to have Velikovsky's ideas tested. Although Einstein did not personally act on this intention, his estate did posthumously, but unsuccessfully.

When Einstein died, his copy of the German edition of *Worlds in Collision*, laden with marginal notes, lay open on his desk.

No clearer example of Oberg's one-sidedness exists than his failure to note Velikovsky's prediction, in the same 1953 Forum Lecture, that the Earth's magnetosphere reaches the Moon. When made, scientists considered the magnetosphere to be confined within the ionosphere. In 1964, Ness discovered that to leeward of the Sun, it reaches the lunar orbit.

Regarding lunar craters, Oberg refuses to concede any credit. Velikovsky said that areas of anomalously high radioactivity would be found on the Moon centered particularly in the rayed craters. The

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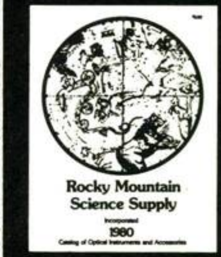

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Apollo 15 alpha particle spectrometer measured an excess of radon-222 at Aristarchus, a rayed crater, that is at least a factor of four higher than the lunar average. Moreover, the Apollo 15 experiment with the gamma-ray spectrometer excluded the possibility of an excessive uranium concentration in Aristarchus. The only possible source for the radon (the half-life of which is 3.8 days) is a high concentration of radium-226 (with a half-life of 1620 years). Dr. Mage concludes his discussion of this point with: "The source for the radium concentration could not be tens-of-thousands, let alone billions, of years old, but if it was produced by a Velikovskian thunderbolt striking Aristarchus some 2,700 years ago, more than a quarter of it would still be there emitting radon-222."

Oberg is skeptical of cosmic thunderbolts being hurled "across the vacuum of space" (space is not a vacuum) and having created many lunar craters and sinuous rilles. However, Ralph Juergens explained all this in *Pensee* in the early 1970s and Fred Jueneman recapped it to Oberg in a letter dated January 7, 1979. On these Oberg is mute.

Selenologists may have been too quick to reject a Velikovskian cause for lunar remanent magnetism. Oberg states: "The fossil magnetic fields appear related to random impact events..." This presumes that craters were formed by impact or volcanism. Juergens pointed out: "Some or all of the lunar remanent magnetism...could be due to cosmic electrical discharges. It is no secret that terrestrial lightning strokes to rocky surfaces...magnetize surrounding rocks without melting them." The foregoing should be considered in light of the fact that Velikovsky reported innumerable references from the ancients to cosmic electrical discharges.

Oberg's outrageous attempt to discredit Velikovsky's prediction regarding the heat of Venus by asserting the superiority of the runaway greenhouse effect fails egregiously. Last October, Verner Suomi of the University of Wisconsin concluded that "the greenhouse effect alone is unable to account for the high surface temperatures." According to Richard Kerr in the January 18, 1980 *Science*, "...each [of the Pioneer Venus probes] found more energy being radiated up from the lower atmosphere than enters it as sunlight...the size of the apparent upward flow of energy varies from place to place by a factor of 2, which was a disturbing discovery about a planet thought to be relatively uniform."

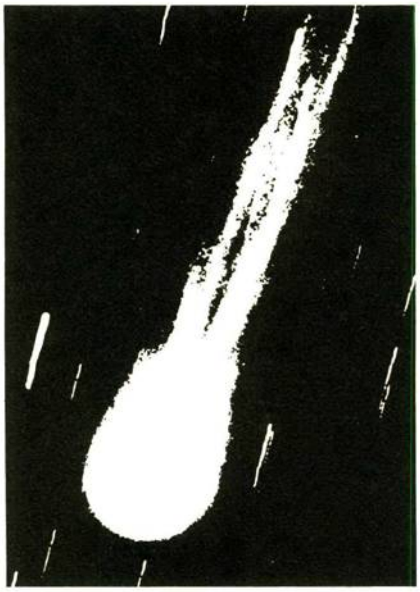
In addition, the central Velikovskian contention of Venus' relative youth is now supported by the discovery that the atmosphere contains some 200 to 300 times more primordial argon-36 than Earth, but substantially less argon-40 (produced by the radioactive decay of potassium-40 in crustal rock). The excess of volatile noble gases also includes neon and perhaps krypton and xenon as well. According to Drs. Wetherill and Drake in *Science* (July 4, 1980), "There is no way the greenhouse effect can cause this difference...It seems almost certain that this excess supply of noble gas has been present on Venus ever since the planet was formed..."

According to the dominant pre-Pioneer Venus model of solar system evolution, Earth lost its primordial gases when the young Sun flared up. So would Venus, had she been present. Jupiter, far from the Sun, would have retained its primordial atmosphere which Venus, in Velikovsky's scenario, would have carried with her when she was expelled within the memory of man. Only *ad hoc* post-Pioneer explanations have displaced this reasoning.

Oberg is also wrong implying that Velikovsky claimed infallibility. When Velikovsky did not yield in the case of the amount of argon on Mars, he was only following common sense in not changing his theory until it had been proven wrong. Why should Velikovsky have emphasized minor "mistakes" when many serious false charges had not been conceded by the critics? When Velikovsky said, in 1974: "My *Worlds in Collision*...does not require any revisions," he meant because no section had been so superseded by new discoveries that its main point was invalidated. In the forward to *Ages in Chaos*, Velikovsky wrote, "I claim the right to fallibility in details, and I eagerly welcome constructive criticism."

Is science as flexible as Oberg says in his last paragraph, talking about the growth and change of science? In principle, and by its nature, science is open and flexible, but it does not follow that scientists are open and flexible. As Thomas Kuhn amply documented in *The Structure of Scientific Revolutions*, the predominant behavior of scientists is the opposite. While unthreatening new information (such as a better diameter for Venus) is readily incorporated into science, revolutionary new ideas (such as the Velikovskian recent origin of Venus) are not accepted. They are threatening, and mean changing or giving up currently-held, fundamental beliefs.

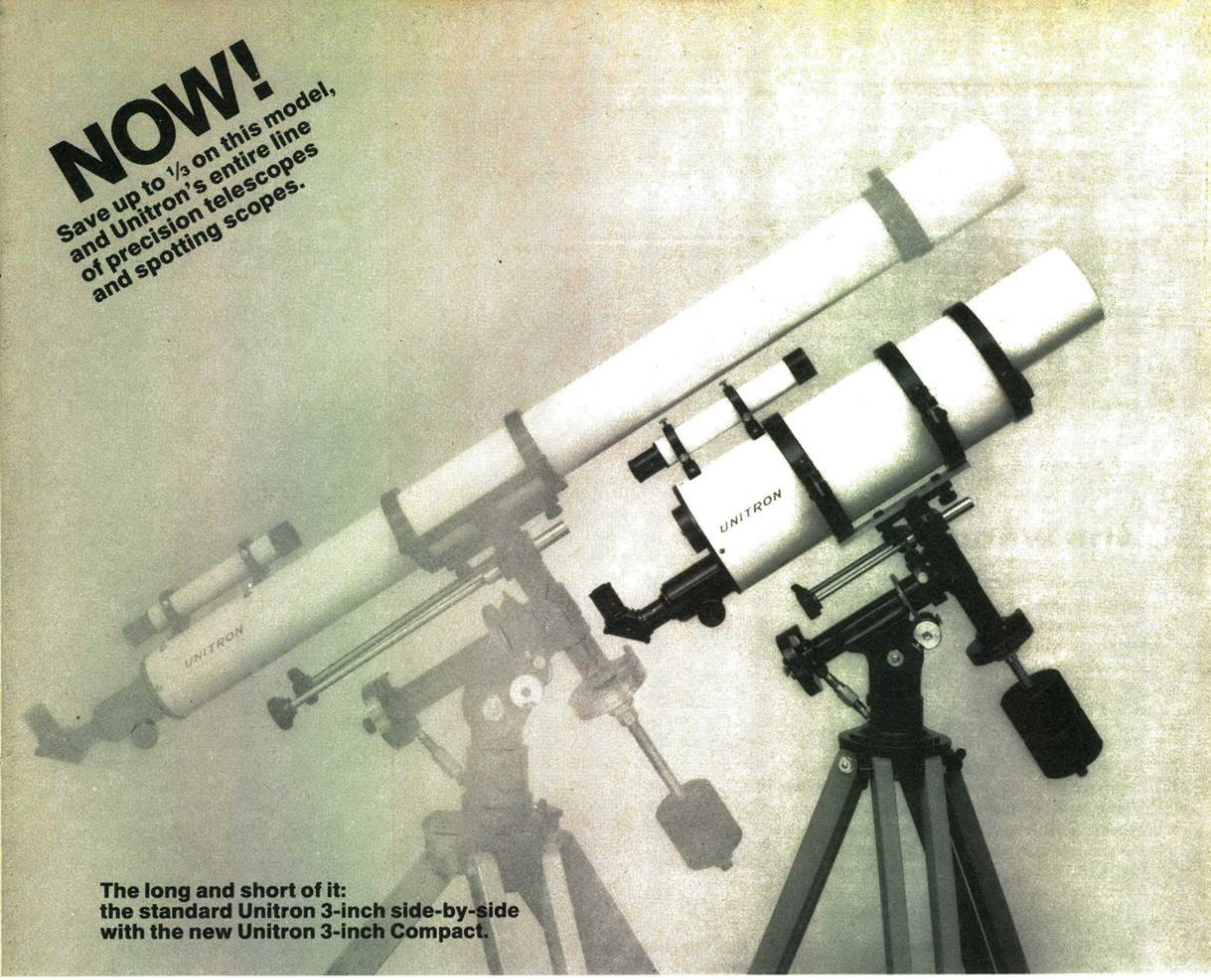
This points out a serious weakness in Oberg's approach: Since Velikovsky's work challenges all the uniformitarian assumptions underlying most disciplines, it is incommensurable with the paradigms of current disciplinary science. Using uniformitarian interpretations of space probe data, as Oberg does, any refutation of Velikovsky is merely an exercise in circular reasoning. If, for example, during the events Velikovsky described, radioisotope decay rates accelerated, then current radioisotope dating techniques would lead to spuriously old ages. Without considering Velikovsky's work on its own terms, refutations such as Oberg's are simply exercises in begging the question.



This is not to say that Velikovsky's scenario is without its difficulties. Investigators are working on such problems as circularization of planetary orbits within a Velikovskian time frame, and the energy disposal problem accompanying the orbital changes implicit in *Worlds in Collision*. Even the latter can be eliminated if a hitherto unknown interloper is allowed into the scenario, but *ad hoc* games are to be avoided.

In light of the ramifications of Velikovsky's reconstruction of planetary and ancient histories, extending literally to all our sciences, philosophies and religions, if there is something that does not accord with present conceptions, should it not stand as a challenge to study, rather than an excuse for dismissal? Should the occasional "error" be an excuse to dismiss Velikovsky's ideas totally? The reader, together with Mr. Oberg, might do well to ponder just whose "theories remain frozen in a universe littered with theories long since abandoned as obsolete."

C. Leroy Ellenberger
Associate Editor, *Kronos*
Landover, MD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eye
on the
sky

autumn's watery constellations

the wanderers

September's dearth of planets in the evening sky continues into October: of the naked-eye visible planets, only Mercury and Mars can be found there. But, as we'll soon see, the mornings to come have a lot to show, so start getting up early!

This month, **Mercury's** orbital motion places it to the east of the Sun in the sky, the point of maximum separation (greatest eastern elongation) happening on the 11th. Normally, this would raise Mercury up where you can see it, even if only for a week to 10 days. But at this elongation, Mercury's position is so far south on the celestial sphere that people watching from the northern hemisphere scarcely catch a glimpse of it.

If you're really determined, take a look in the west-southwest on or near the horizon on the evenings of October 11th to 15th, starting about half an hour after the Sun has set. You're looking for a tiny point of light in the sunset sky and binoculars will certainly help.

Mars is easier to locate when darkness falls because it'll be about 10° high in the southwest during the entire month. (10° is about the width of your palm held at arm's length.) However, you'll need a viewing site with no buildings or trees to the southwest. Provided the atmosphere is unhazy, discerning the little orange point of light low in the twilight glow shouldn't be too hard.

Late in the month, on the evening of the 24th, Mars will pass to the north of its stellar "namesake," Antares, the brightest star in Scorpius. Forty-five minutes after sunset on the 24th, Mars will be almost 10° high with Antares about a "thumb's width" lower; both will lie in the southwest. Antares shines slightly brighter.

The rest of the planetary action comes in the morning sky, so let's skip ahead to the pre-dawn hours and see what's up.

During the first week of October, **Venus** will be close to Regulus, the brightest star of Leo. This spring constellation is rising in the east shortly before the Sun. On the mornings of the 4th and 5th, Venus will be at its closest to the star.

Neatly bracketing Venus and Regulus on these mornings will be the crescent **Moon**. On the 4th, it'll lie above and to the right of the pair; a day later, you'll see it below and to the left. Two mornings later (the 7th), the Moon, having become even more slender, will meet Jupiter down very low near the eastern horizon.

By the morning of the 30th, **Jupiter** will have risen high enough in the sky to be close to Venus. Look a little south of east as dawn begins to lighten the sky and you'll see them both. Better yet, start looking several days ahead of time and get daily "snapshot" views as they gradually move toward conjunction.

Saturn also is in the morning sky, but lies much too close to the Sun to be seen until the end of the month. It'll be appearing slightly to the south of east during the last week of October.

October's main meteor shower is the **Orionids**, which appear to come from a part of the sky to the north and east of Betelgeuse, the ruddy first magnitude star in Orion's left shoulder. The shower is nowhere as plentiful as August's Perseids and the Moon will interfere most of the night in question (the 20th to the 21st). You shouldn't expect too much from them this year.

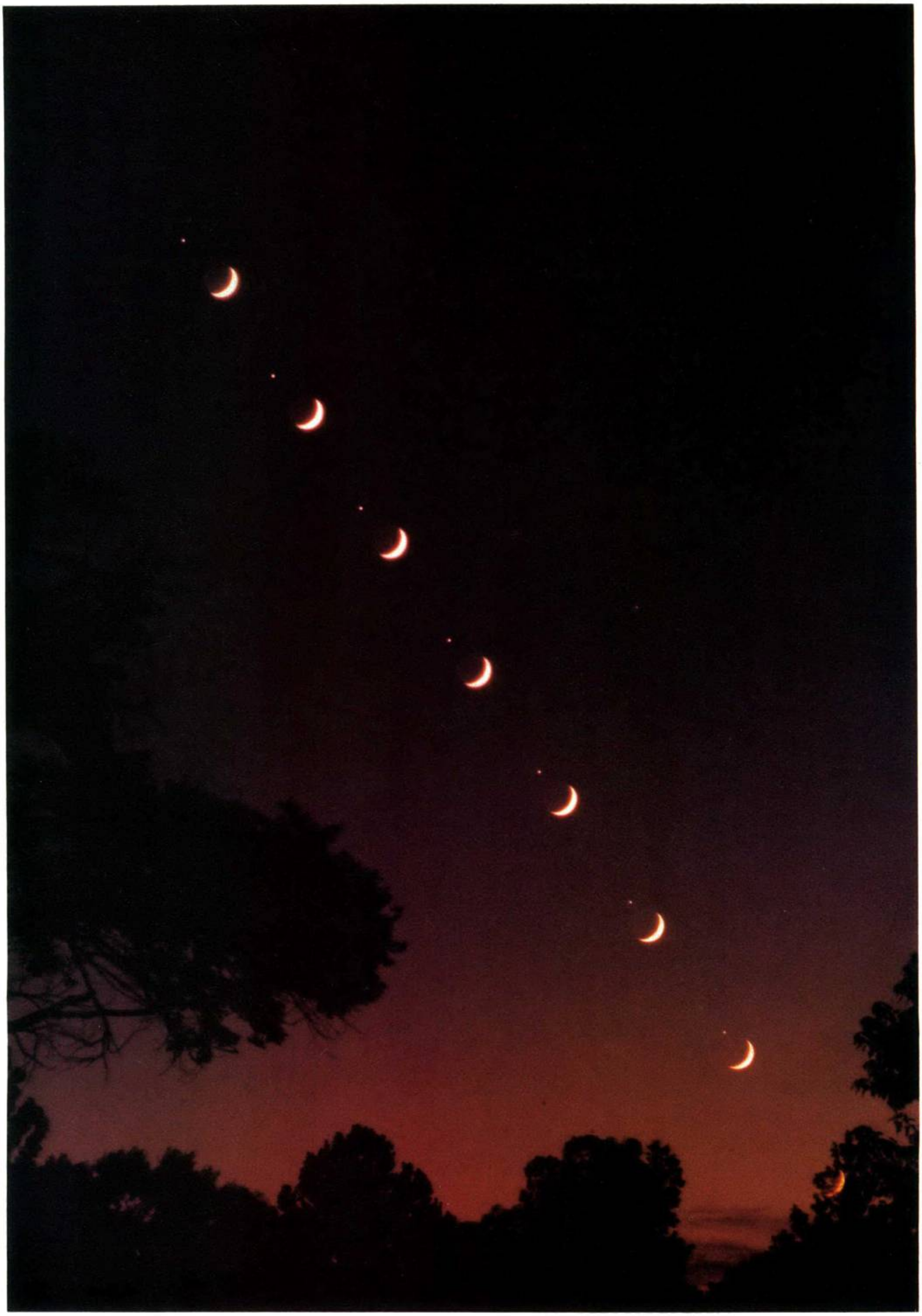
the starry sky

Even though the **Big Dipper** is what is called an *asterism* rather than a true constellation, almost everyone, even those who know nothing of astronomy, can easily recognize it in the night sky. This is understandable for several reasons. First, the Dipper is relatively compact and made up of bright stars with a distinctive, easily recognizable pattern. Also, the Big Dipper is a very useful asterism to know, because it not only can be used to locate **Polaris** — the North Star — but a number of other stars and constellations as well, so it is usually the first stellar formation you learn. And finally, as a circumpolar asterism in the north temperate latitudes, it never sets and can thus always be found in the sky.

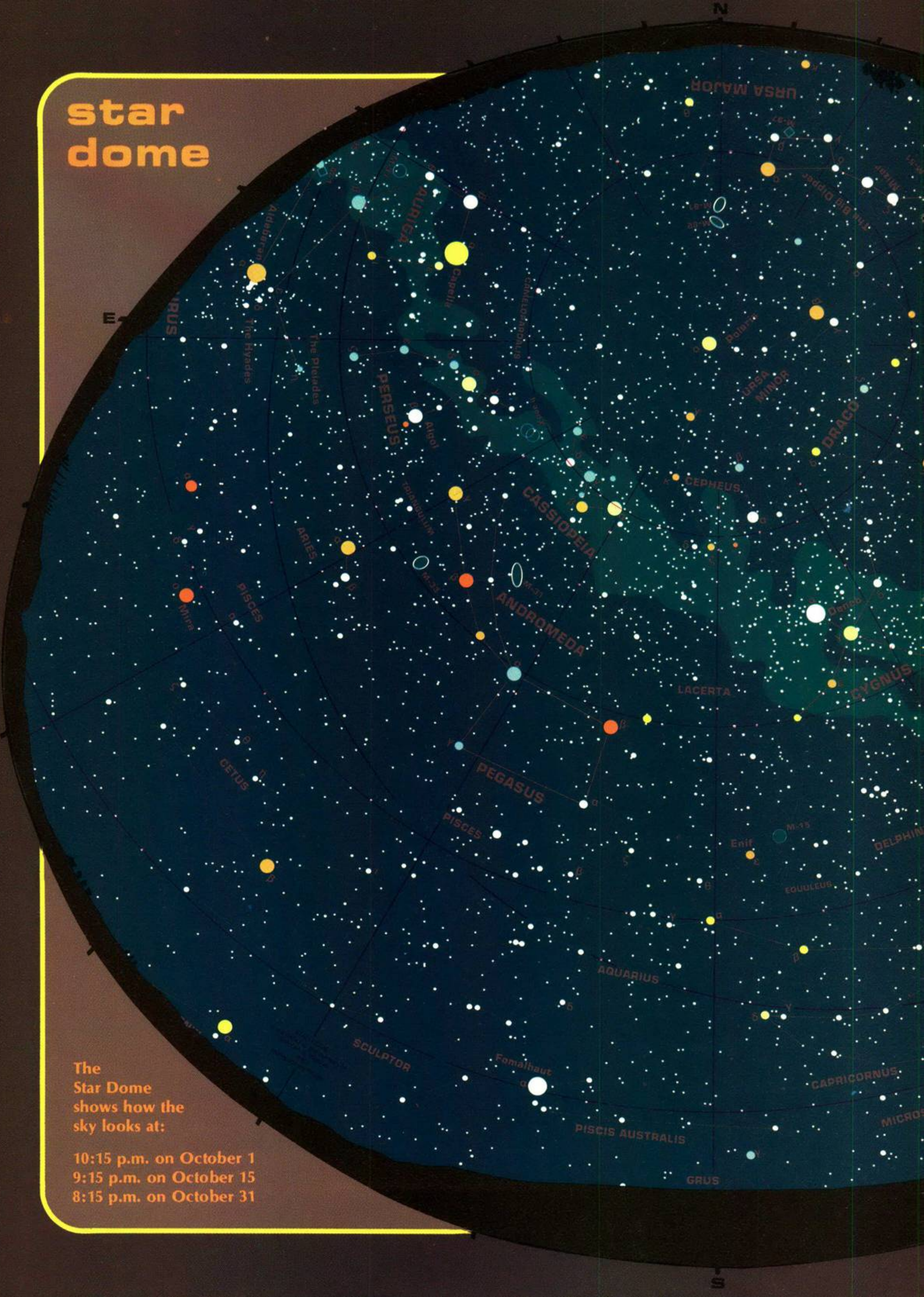
But those whose knowledge of astronomy is limited to identifying the Big Dipper may have a problem this month, since on October evenings this famous asterism lies at its lowest elevation, riding just above the northern horizon. Unless you know just where to look, the Dipper could well escape notice, leaving you to founder about in an unknown starry wilderness.

Fortunately, though, autumn evenings have other stellar landmarks to help the neophyte find his bearings. Foremost of these is the famous **Summer Triangle**, still high above the western horizon early in the evening throughout this month. The highest of the three brilliant white gems you'll see is **Deneb**, marking the top of the **Northern Cross** (whose "official" name is **Cygnus** — the swan). Lower and more to the north, the brightest of the three is **Vega**, *luminar* (a term which simply means "brightest star") in the compact and distinctive constellation **Lyra**. Farther to the south

As the Moon set on the evening of July 15th, it drew ever nearer to Jupiter. William Sterne, Jr. recorded their stately progress by taking an exposure every 10 minutes. Compare how close the Moon and Jupiter are in the last exposure (at bottom right) with their relative positions at first (top left). See also page 83.



star dome


N
E
S
URSA MAJOR
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The Big Dipper
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URSA MINOR
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Mira
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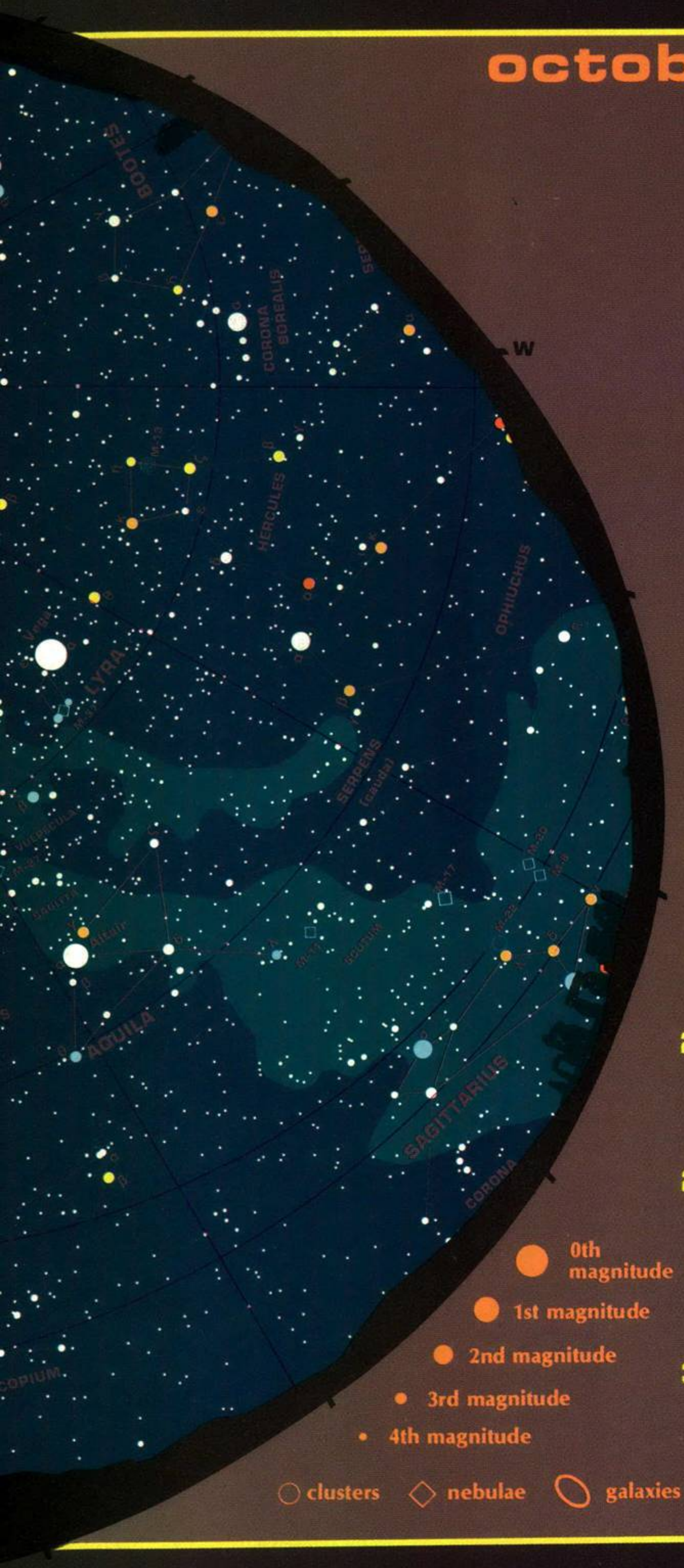
M-31
ANDROMEDA
Deneb
CYGNUS
LACERTA
CETUS
PEGASUS
PISCES
Enif
M-15
DELPHIN
EQUULEUS
AQUARIUS
SCULPTOR
Fomalhaut
CAPRICORNUS
MICROS
PISCIS AUSTRALIS
GRUS

The Star Dome shows how the sky looks at:

10:15 p.m. on October 1
9:15 p.m. on October 15
8:15 p.m. on October 31


BOOTES
CORONA BOREALIS
SERPENS
W
HERCULES
M-13
OPHIUCHUS
Vega
LYRA
M-57
SERPENS (Cauda)
VULPECULA
M-27
SAGITTA
Altair
AQUILA
SCUTUM
M-11
M-17
M-20
M-8
SAGITTARIUS
CORONA
COPIUM
0th magnitude
1st magnitude
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

october sky almanac

4th In the eastern sky during pre-dawn hours today and tomorrow, Venus will be close to Regulus in Leo, with the Moon nearby.

7th Half an hour before sunrise, look low in the east and see the Moon and Jupiter together.

8th New moon happens at 10:50 p.m. EDT. The Moon lies in line with the Sun and can't be seen. Look for a "fingernail" Moon in the west a day or so from now. Meanwhile, use the dark and moonless nights for observing.

9th Moon farthest from Earth (apogee), 252,133 miles, this morning.

11th Mercury at eastern elongation today, though all but invisible.

16th First quarter moon comes at 11:47 p.m. EDT tonight.

20th Orionid meteors can be seen coming from near Betelgeuse very late tonight and early tomorrow morning.

23rd Full moon this afternoon (the Hunter's Moon) at 4:52 p.m. EDT; also closest to Earth (perigee), 221,191 miles, in the morning hours.

30th Last quarter moon today at 12:33 p.m. EDT. As twilight begins this morning, look east to see Venus and Jupiter together.

Venus was low in the evening sky when Richard Knoll snapped this shot of it and a crescent moon. Photos like this are relatively easy to nab. Use a suitable focal length lens (his was a 200 mm) and bracket your exposures around what the camera's meter calls for; Knoll used a ¼ second at f/4 on Kodachrome 64.

you'll see the third, **Altair**, luminar of **Aquila** the eagle.

Interestingly enough, while both Altair and Vega are relatively nearby neighbors of our Sun (respectively 16 and 27 light-years distant), Deneb lies at a vast distance — about 1600 light-years. Its apparent brightness, nearly the same as that of Vega and Altair, is due to the fact that despite its distance, Deneb is intrinsically many thousands of times more brilliant than either of the others — in fact, it is one of the brightest of all supergiant stars. If Deneb were as near to us as Altair or even Vega, it would be the brightest object in the sky after the Sun and Moon — brighter even than Venus at its brightest!

Now look a little to the east of the *zenith* (the point directly overhead in the sky). See if you can pick out the four stars marking the **Great Square of Pegasus: Markab** (α or Alpha), **Scheat** (β or Beta), **Algenib** (γ or Gamma), and **Alpheratz** (actually Alpha [α] of the constellation Andromeda). Follow the double line of stars down from Alpheratz to the east, and you have located **Andromeda**, seemingly dangling from the great winged horse's flank.

A constellation which is almost as distinctive as the Big Dipper rises higher in the northeastern sky on October evenings. The characteristic "W" (or "M", depending on which way you twist your head) shape of **Cassiopeia** should be easy to pick out. If you are interested in star names, an unusual project would be to learn the names of all the stars making up the "W" of Cassiopeia. Going up from the horizon to the highest, these stars are named **Segin**, **Ruchbah**, **Cih**, **Schedar**, and **Caph**.

Cassiopeia lies right in the midst of the Milky Way, which stretches across the October evening sky from northeast to southwest. Follow this starry path down to the northeastern horizon, and there, hovering low in the sky, you'll find the lovely golden-white star **Capella** — perhaps looking more red because of its low elevation. Capella is the brightest star of the famous **Pentagon of Auriga**, a familiar winter asterism that will rise higher in the sky as the evening progresses. The Pentagon of Auriga, like the Great Square of Pegasus (which includes Alpha Andromedae), is an asterism rather than a constellation because it includes a star properly belonging to another constellation — in this case, **Elnath**, Beta of the constellation Taurus.

Even closer to the horizon (and more toward the east) you can see **Aldebaran**, the luminar of Taurus, rising on October evenings. Here the ruddy color is not entirely due to atmospheric absorption, for Aldebaran has a distinctive orange color itself.

Between Andromeda and Cassiopeia on the one hand, and Capella and Aldebaran on the other, you'll find a rich region marked by the numerous stars of the constellation **Perseus**. See if you can locate **Algol**, the so-called "Demon Star," famous for its variability. Algol is an eclipsing variable, and every 2.87 days it dims perceptibly as though winking evilly at us.

Stretched across the southern sky from the southwest to the east is the "watery" part of the sky, containing a number of relatively dim, more or less aquatic constellations. Using our Star Dome chart, see if you can pick out **Capricornus** (the water goat), **Delphinus** (*the dolphin*), **Aquarius** (the water carrier), **Pisces** (the fishes), and **Cetus** (the whale). But be warned:

you'll need especially clear nights away from city lights to trace out these dim patterns! First try to see the **Circlet** of Pisces, a ring of 4th and 5th magnitude stars just below the Great Square. Follow the line of stars extending from the Circlet to the east to **Al Rischa**, the "knot" of the cords binding together the two fish of Pisces. And just above the southern horizon you should be able to easily find the only bright star in this part of the sky: **Fomalhaut**, which means "the fish's mouth," marking the constellation **Piscis Austrinus** (the southern fish).

These watery constellations, whose presence in the evening marks the coming of fall, are rather disappointing in appearance, but take heart: they will soon be followed by the rising of the great winter constellations Taurus and Orion — the latter, like the Big Dipper, one of the few stellar patterns familiar to nearly everyone.

skylore

In October, the "watery" part of the sky rises above the southeastern horizon in the early evening, heralding the coming of the rainy season in many parts of the world (see Star Dome in the November 1979 ASTRONOMY). The constellations in this region are all very ancient, but aside from having an aquatic character, they have never been tied together into a single myth. Instead, each one has its own story, although in the case of Cetus the stellar figure is related to the story of Perseus and Andromeda, the great mythic cycle of the northern fall sky.

Cetus is supposed to represent the great sea monster sent to devour the chained Andromeda, from which culinary fate she was delivered by Perseus (for an illustration of the action by the great nineteenth-century artist Gustave Dore, see p. 35 of the May 1980 issue). Cetus was turned to stone by the sight of the Gorgon's terrible head in the hand of Perseus. In case there is any doubt as to the veracity of this tale, let it be known that long ago a certain Scaurus (who, we may suppose, was a sort of ancient side-show entrepeneur) actually brought to Rome the bones of the fearful creature and put them on display there. The first-century Roman naturalist Pliny viewed the remains (for, we assume, some modest fee) and recorded that the skeleton measured forty feet in length, with ribs six feet long!

Be that as it may, there is little doubt that the Cetus of the myth was not, in fact, a whale — although that is usually the identification today. The monster was always portrayed as being a sort of hodgepodge of beasts ferocious, with paws, tusks and horns, and horrible scales. There is undoubtedly a correlation here to the "Leviathan" and the "great fish" of the story of Jonah in the Bible — creatures also unknown to us but later identified with whales (which, of course, are not fish at all, but mammals).

The story of Cetus as a fearful sea monster is probably much older than the tale of Perseus and Andromeda in which he later appeared. There is some evidence that Cetus was originally seen in ancient Babylon as Tiamat, the Monster of Chaos, out of whose slain body the god Marduk created the universe. But Tiamat was more clearly a serpentine beast, and is more commonly identified with Draco, Serpens, or Hydra.

The zodiacal constellation Pisces also has a history which may go back to the ancient Near East. According to a Syrian tale, the goddess Astarte cleverly effected an escape from the fire-breathing dragon Typhon by leaping into the Euphrates River and changing herself and her son (who happened to be along on the outing) into two fish. But the Greeks and Romans, who were adept at identifying their own gods among the pantheons of other peoples, changed Astarte and her son into Aphrodite (or Venus) and Eros (or Cupid). Venus and Cupid (to use the Roman names) tied themselves together with a cord so that they would not lose each other in the depths, and this is the reason the fish are seen with their tails bound by lines anchored to the star Al Rischa.

Typhon himself, who was one of the rebels in the Battle of the Giants against the gods, was finally defeated by Jupiter and cast to the bottom of the Mediterranean. To hold him there forever, the island of Sicily was dropped on top of him with Mount Etna marking his head. But the monster was not destroyed, for from time to time Mount Etna erupts with fire and steam as Typhon rages at his captivity. Hearing this, you may be moved to wonder what dragon has been buried under Mt. St. Helens, and by whom!

Of course Pisces is also marked by the presence of the vernal equinox, located within its confines since the precession of the equinoxes brought it there from Aries nearly two thousand years ago. Still referred to as the "First Point of Aries," the equinox will eventually move into the constellation of Aquarius. This movement of the vernal equinox through the constellations of the Zodiac has been regarded by some astrologers as marking successive ages of the world. It is for this reason that we sometimes hear that we are now living in the "dawn of the Age of Aquarius," although, since the astrological Houses do not correspond to the astronomical constellations, it is not entirely clear just when the "Age of Aquarius" will begin.

According to this reckoning, the Age of Pisces (which is now coming to an end) is to be identified with the Christian era, for the vernal equinox moved into the House of Pisces about the time of Christ. And in fact a fish *was* an early Christian symbol for Christ himself, though no one has managed to show that this was due to any astrological influence in early Christianity. Rather it seems that the fish was adopted as a symbol because the letters of the Greek word for "fish" happened to form a convenient acronym, being in order the first letters of the Greek words meaning "Jesus Christ, the Son of God, the Savior."

It is true, however, that Pisces has long been regarded as an astrological sign with particular relevance for the Jewish people. An old Jewish tradition has it that a planetary conjunction took place in Pisces three years before the birth of Moses, and that a similar conjunction would herald the birth of the Messiah. The astronomer Kepler, noting this Jewish tradition, pointed out that in fact a triple conjunction of the planets Jupiter and Saturn occurred in Pisces in 6 B.C. and suggested that this unusual apparition was the "Star of the Magi." He argued that the ancient astrologers in Babylon would have been familiar with the tradition linking Pisces with the Jewish people, and a conjunction there with the birth of a king or great leader like Moses.

Repeated many times since Kepler and elaborated on by other scholars, this tale has come down to us as an almost established fact. Many planetariums present Christmas shows in which Kepler's famous conjunctions are re-enacted, and the story has been told so many times that few question it anymore. Unfortunately, more recent research has uncovered a number of problems. Most importantly, it has been pointed out that the Jewish tradition connecting Pisces, conjunctions, Jews, and leaders such as Moses and the Messiah cannot be traced back any further than the fifteenth century C.E. Therefore there is no evidence that for the ancient astrologers such a conjunction in Pisces would have had the meaning Kepler and the fifteenth-century rabbis asserted it would. In addition, there are a number of problems with the chronology of known historical events at that time which were previously unrecognized.

Still, it *is* a nice story and it *was* a beautiful conjunction in a rather dim constellation, so it *does* make an impressive Christmas show.

ASTRONOMY
IN FOCUS

Velikovskian Fallout

Sir / Congratulations on the update on Velikovsky in the July 1980 issue. As an ancient historian, I am constantly being asked or told about von Daniken and, less frequently, Velikovsky by students who apparently need human history to be more exotic than it already is. Von Daniken is a complete charlatan who knows next to nothing about the ancient history of the Near East and does not have the intellectual tools to argue cogently from the few real facts he has. Velikovsky, on the other hand, deserves a bit more consideration, if only because he is capable of producing a scholarly argument. Obviously the crux of Velikovsky's theories is his strange notions of astrophysics and probabilities, which even *I* can see to be next to nonsense.

Let me say with regard to my area of expertise, however, that Velikovsky also plays very fast and loose with his ancient history, shading facts and especially manipulating chronology to fit his ideas. It is interesting that both of these individuals rely very heavily on myth and the other literature of the world's religions in order to support theories which debunk those religions.

Richard M. Berthold
Asst. Prof. of History
The University of New Mexico
Alberquerque, NM

Sir / The article, "Predictions in Collision," suggests thats James Oberg should re-examine his philosophy of science. *Detailed predictions* are to be associated with detailed theories about quarks or quasars. However, there are also such things as insights into historical matters that provoke general inferences. Although he does not say that a theory of large scope is necessarily a waste of time, Oberg shows no appreciation of the fact that inferences from such a theory cannot be precise.

Perhaps Oberg is not acquainted with history and assumes that nothing ever happened except what modern astronomers deduce happened some billions of years ago. For example, perhaps he cannot find any significance to the picture of the Sumerian goddess Inanna, considered by our scholars to have been the planet Venus, on a cylinder seal from Urak as a comet — a "head" standing on a flowing tail.

On the other hand, he has provided a useful summary of the current state of the astronomical evidence as viewed by astronomers, and this is something an open-minded person appreciates.

Harry E. Mongold
Manhattan, IL

Sir / Bravo for the excellent discussion of Velikovsky by James Oberg in the July 1980 issue. While not all astronomers may agree in detail with each of his points — personally, I tend to give Velikovsky more credit than Oberg does for the prediction of radio emission from Jupiter — the overall picture is beyond dispute: Velikovsky's "predictions" have not stood the test of time. This is not just an intellectual game of predictmanship; many of the contradictions between Velikovsky's expectations and the facts, such as those associated with the great antiquity of the lunar surface and its volatile-depleted chemistry, provide definitive tests of Velikovsky's ideas. There is no way the recent near-collisions he suggests among Earth, Venus, and Mars could have taken place without leaving traces on the Moon. ASTRONOMY has done a real service by printing this article.

David Morrison
University of Hawaii
Honolulu, HI

Sir / Almost a full decade ago I came to the realization that we need a formal adversary system on the university level if we are to deal in any rational manner with the intellectual output of certain dissident individuals like the late Dr. Velikovsky. James Oberg's recent article, "Predictions in Collision," confirms once again how great the need for the disciplined use of formal adversary procedures really is.

In this context, the publication of Oberg's article in your journal reflects glaringly upon your nonobjective stance towards Velikovsky. Otherwise, why did you not include a rebuttal? Why didn't you let your readers know at least where they could obtain the opposition's point of view on the subject? Considerations of this kind are not only relevant to sound fact-finding procedure, but they would have constituted an elementary aspect of courtesy and respect for other human beings.

Guenter Koehler
Tuscaloosa, AL

The following letter, by the Editor of **Kronos**, *and the rebuttal to James Oberg that appears in this month's Forum (by C. Leroy Ellenberger, an Associate Editor of* **Kronos**), *represent the pro-Velikovsky viewpoint. We feel, whether we agree with it or not, that both viewpoints ought to be presented.*

In our opinion, the entire Velikovsky affair is far more interesting as a study of personalities and emotions than it is enlightening about the nature of the solar system. Although his supporters have shown he received contemptuous treatment from the scientific community, they have not been able to show his theories to be scientifically important or correct. The Velikovskian hypotheses, it seems, are a dead end.

Velikovsky, however, seems to have reaped some benefit (fame, a following, speaking engagements, and a journal devoted to his works) from his "martyrdom" that his theories, by themselves, could not have justified.

Readers who wish to pursue the matter further must obtain a copy of **Scientists Confront Velikovsky** *(Norton, 1979), $3.95 in paperback. In this book, edited by Donald Goldsmith, Isaac Asimov brilliantly analyzes the role of scientific "heretics"; Norman W. Storer discusses the sociological context; Carl Sagan raises a formidable array of problems for the Velikovskian hypothesis; J. Derral Mulholland debunks some of Velikovsky's orbital notions; Peter Huber shows, on the basis of cuniform texts, that Venus apparently existed in antiquity; David Morrison discusses planetary science from viewpoints of uniformitarianism and catastrophism.*

Velikovsky's books are also still widely available, required reading for both debunkers and those who would follow Velikovsky. The journal **Kronos** *presents a consistantly pro-Velikovsky stance. Much of their effort goes into searching out errors in* **Scientists Confront Velikovsky** *and pressing the claim that Velikovsky has been misquoted, misunderstood, and has not received due credit.*

Another journal worth mentioning is the **Skeptical Inquirer**. *It is devoted to the discussion and debunking of all kinds of pseudo-science and the paranormal.*

Oberg under Attack

Sir / It is incumbent upon any critic who would attack highly controversial theories to be dispassionate, temperate, and precise. In the case of Oberg's critique of Velikovsky's cosmological prognostications, the snide invective that passes for objective criticism automatically disqualifies Oberg on the first two prerequisites; a few selected examples should suffice to show him sorely wanting in the latter....

To begin with, Oberg refers to Velikovsky's prediction of "lunar remnant [sic] magnetism." The correct term is "remanent magnetism"; and the appearance of the word "remnant" no less than three times in Oberg's criticism shows that his error is something more than merely typographical.

With respect to moonquakes, Oberg should consult the October 1971 issue of *Chemistry*. There, he will find a NASA report of 11/20/70 to the effect that equipment left on the Moon by Apollo XII recorded an average of one lunar quake a day, with more severe quakes occurring once a month. This hardly sounds "rare"....

Oberg's remarks about Venus are also slipshod and behind the times. The runaway greenhouse effect may still be limping along but it is barely in the running. The most up-to-date brief on the weaknesses of the proposed greenhouse effect may be found in *Kronos* V:2, Feb. 1980, pp. 87-88. Since Oberg first completed his published critique of Velikovsky in February of 1980, he was obviously too lazy to incorporate the *Kronos* material even though he subscribes to that journal.

When we turn to Mars, we find Oberg's reporting equally faulty. For example, he states the following: "Writing in the pro-Velikovsky journal *Kronos* in 1977, the then editor-in-chief, Lewis M. Greenberg, made the excuse that 'the relatively low amount [of argon] might be the result of an argon loss to the Earth, the Moon, and interplanetary space during the celestial events described in *Worlds in Collision*' (the argon was kidnapped!)."

Let it be shown here, for starters, that I am still the Editor-in-Chief of *Kronos* and have been on a continuous basis since the journal's inception. Secondly, my exact words on the argon were: "IF the '1 to 2 percent of the by now nearly notorious argon' (in the words of *Science News*) should prove to be a correct figure, the relatively low amount MIGHT be the result of an argon loss to the Earth, the Moon, and interplanetary space during the celestial events described in *Worlds in Collision*..." (n.b., emphasis was present in the original text just quoted). The reader was then referred to additional textual discussion as well as an article in *Nature*. Oberg has lifted my words out of context, omitted the emphasis, and disregarded the references. This is hardly the hallmark of proper scholarship and criticism....

Finally, I find it highly amusing that Oberg should refer to Ralph Juergens as "another leading Velikovsky disciple." Aside from the fact that Juergens predeceased Velikovsky by two weeks, Juergen's critical approach and independent thinking — a far cry from Oberg's — do not allow Juergens to be categorized as a mere follower. By contrast, in a letter to *Kronos* (dated 12/14/78), Oberg said: "...I'd be a valuable convert." Unfortunately for him, Kronos does not proselytize. Besides, with a performance like his, the other side can keep Oberg. Those of us who support Velikovsky are interested in intelligent free thinkers, not the ghost of Carl Sagan.

Lewis M. Greenberg
Glassboro, NJ

A rebuttal by C. Leroy Ellenberger (entitled "Oberg in Confusion") to James Oberg's Forum article, "Predictions in Collision," appears in this month's Forum.

behind the scenes

joys and headaches

An editor's biggest headaches happen when copy gets lost. When our Art Director Tom Hunt brought the proof sheets back for the September issue, we folded, cut them, and stapled together a handmade copy of ASTRONOMY for quick inspection. That night, I took it home, sat down in my comfy chair, and began to read David Morrison's feature article on the new worlds of the jovian system. When I got to the table at the top of page 18, I scanned down the table: Pluto, Europa, Io...where's the Moon? No Moon. It lies between Europa and Io in diameter. It's missing!

So here's the missing Moon data: diameter, 3476 km; Mass, (Earth = 1) 0.012; Density, 3.3 grams/cm^3; daytime temperature, 380 K; no atmosphere.

Next: We're still working on that supernova (see Behind the Scenes last month). If any reader knows of, or has a picture of, NGC-5364 taken in March, April, or May 1979, we'd appreciate seeing it.

Finally: The November 12 Voyager 1 flyby of Saturn and Titan is going to be an extremely exciting event. Our December issue will be printed during the first week in November, so the big flyby story will appear in the January 1981 issue. We plan to have follow-ups in the February and March issues. However, we think we'll have some super-sharp far encounter images in time for the December issue, maybe even on the cover! Cross your fingers...

Sincerely,
Richard Berry
Richard Berry

MARS

The new addition to ASTRONOMY's planet poster series features the awesome Olympus Mons rising 15 miles high and 400 wide from the clouds of the Red Planet. The great caldera and massive shoulders of the solar system's largest shield volcano are the most dramatic images returned by the Viking spacecraft.

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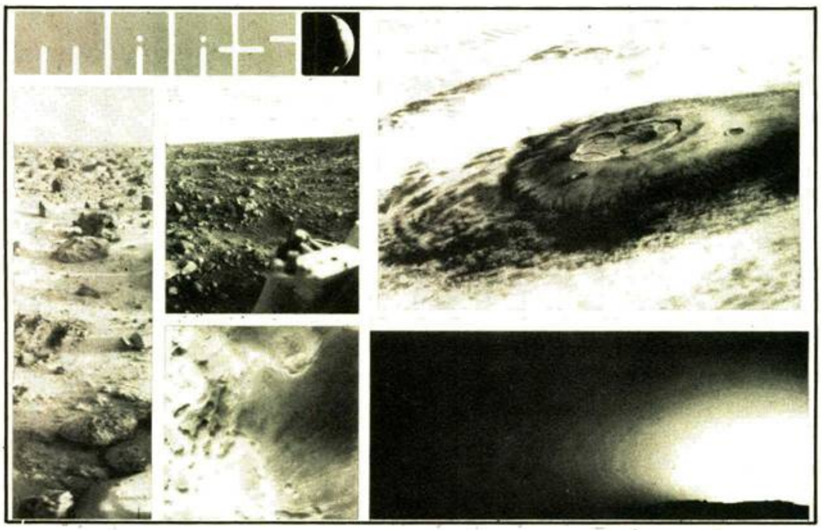

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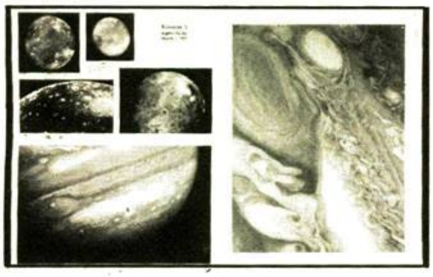
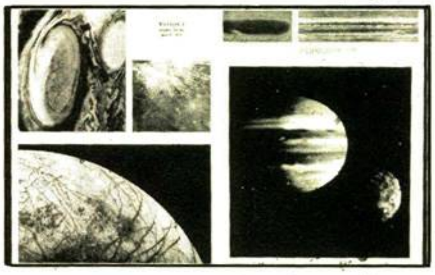


Voyager 2



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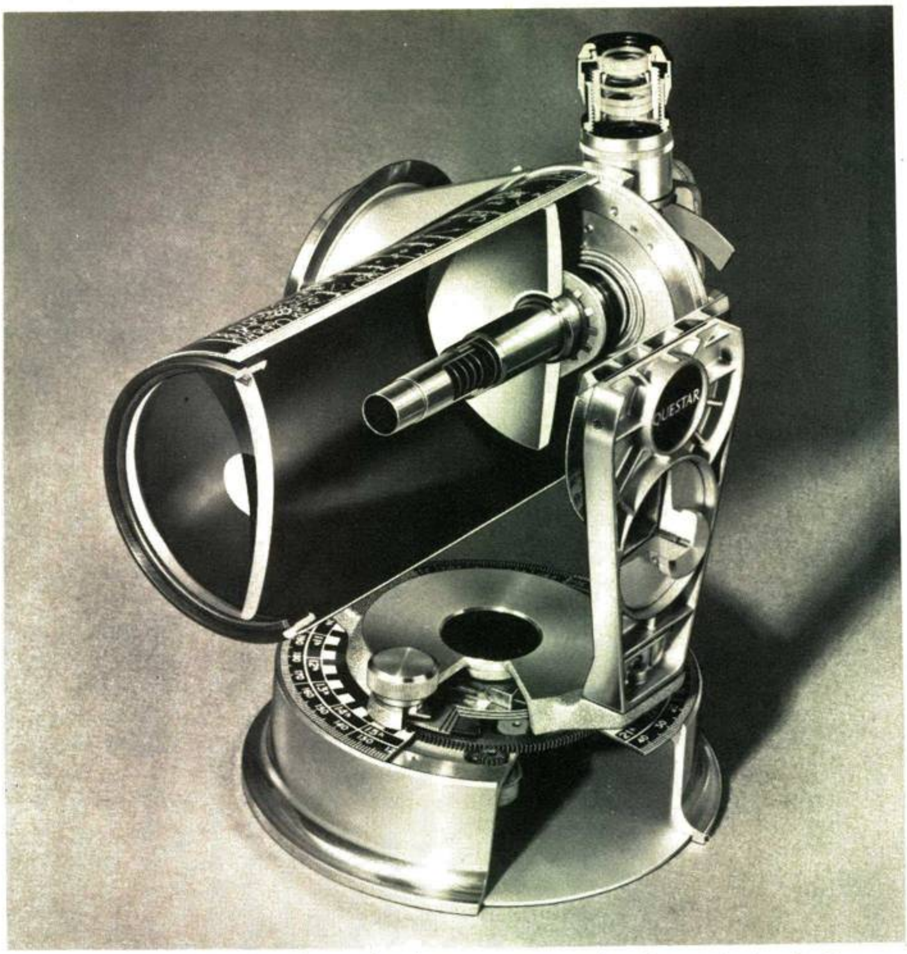

Our first ad in *Sky and Telescope* appeared early in 1954 and what we had to say was radical for its day. We had a new thing under the sun—a miniaturized version of the classical astronomical telescope. It was so small that it could be used on a table top and carried around in a leather case; a design that had built-in controls for finder, power changes, drives in right ascension and declination, both manual and electrical; and it could focus from infinity down to less than 10 feet.

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gazer's gazette

the zodiacal light

During the middle weeks of October, in the last dark hour before morning twilight begins, a dim glow of light rises in the eastern sky. About as bright as the Milky Way, it's not really the dawn, for the hour is still too early, but perhaps the most elusive naked-eye object in the entire sky: the zodiacal light.

Made of sunlight scattering off minute dust particles circling the Sun roughly in the plane of Earth's orbit, the zodiacal light shows best in the northern hemisphere on spring evenings and fall mornings, when the ecliptic makes a steep angle with the horizon.

Since moonlight obscures it, be outside and looking east every clear morning in the period from new moon until just before full — between October 8th and 23rd.

But not just any old place will do: seek out a rural location with a very dark sky and no cities or towns to the east. If you get a choice, pick a spot on a hill since autumn nights in the country are damp, and ground-fog collects in the low places.

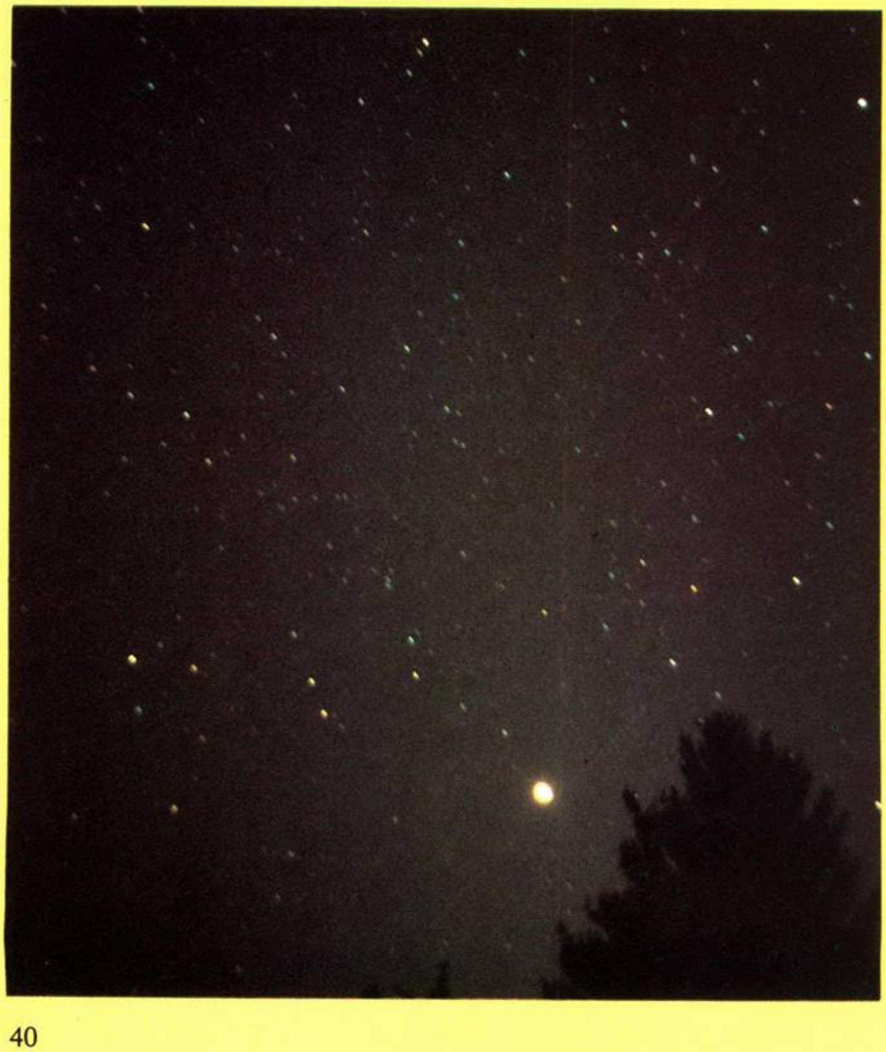
What should you look for? A tall tapering cone of light, brightest near the horizon, that extends up about 40° to 60° to a diffuse edge fading into the starry background: E.L. Trouvelot's drawing (opposite) shows it on a late-February evening, the tip reaching just past the Pleiades. You may well see it fainter than this; if so, try sweeping your eyes past where it should be. Spotting a slight change in brightness comes easiest this way.

The zodiacal light glows most visibly when the Sun lies 20° below the horizon. This is about 2 hours before sunrise in the fall or 2 hours after sunset in the spring. Your "equipment" need consist of only your eyes and sufficient clothing to stay warm — telescopes, even binoculars, won't help.

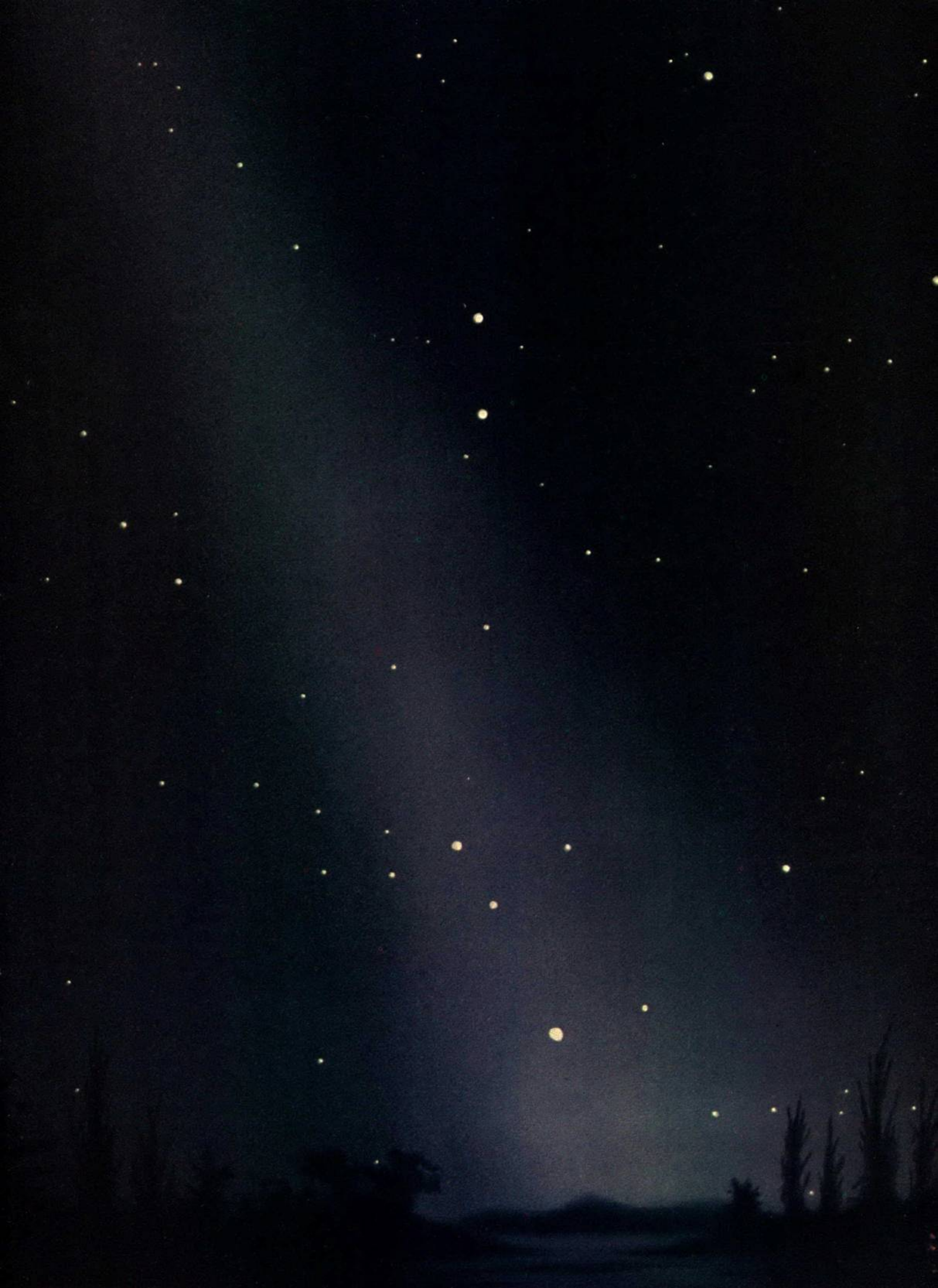
If you have an urge to make sketches, work with a dim red-lensed flashlight to save your night vision. If photography appeals, use fast film, a wide-angle lens, and a tripod. When you see the zodiacal light, take exposures from 30 seconds to several minutes long. (ASTRONOMY would be interested in seeing your results, photographed or sketched.)

Those going out later in the time slot (nearer full moon) could combine their watch for the zodiacal light with that for the Orionid meteor shower, which peaks early in the morning of the 21st.

—Robert Burnham



Right: E. Leopold Trouvelot sketched the evening zodiacal light on February 20th, 1876. This view shows clearly how the light appears to the naked eye. Courtesy of the Fairfield County Astronomical Society. *This page: 104 years later,* J.R. Westlake, Jr. took this 30 second exposure on 400 ASA slide film at f/1.7.



ASTRONOMY
REVIEWS

Atlas of Mars
R.M. Bridges and J.L. Inge
146 pages, hardcover, $7.00
Superintendent of Documents,
U.S. Government Printing Office,
Washington, DC 20402.
(Stock No. 033-000-0078-9/Catalog No. NAS 1.21:438)

The planet Mars is a dynamic world with many Earthlike characteristics: four seasons, annual polar caps, changeable weather, windy seasons, storm clouds, and a large assortment of geomorphological features. A planet's surface must first be mapped before systematic qualitative and quantitative studies can be made of its past and present geology and the interaction of its atmosphere with its surface. Maps are necessary to plot and display the spatial relationships of the seasonal changes and the mysterious, unpredictable long-term dark albedo features that are so well observed with Earth-based telescopes and orbiting space probes.

For this purpose the *Atlas of Mars* was conceived and produced by the U.S. Geological Survey, Branch of Astrogeology, in cooperation with the National Aeronautics and Space Administration. The original consists of 30 individual quadrangle charts in a monotone ocher color, covering the entire surface of Mars. Each chart is designated by the name of a prominent classical telescopic albedo feature within its confines. Each chart has also been assigned a number between 1 and 30 preceded by the letters MC, for "Mars Chart." Most of the charts were compiled with data from the Mariner 9 spacecraft, gathered in 1972. A few charts used information gathered by the two Viking Orbiter spacecraft from 1976 through 1978.

This new publication of the *Atlas of Mars* is a one-half reduced scale black-and-white version of the original topographic series, bound together in a handy 11 x 14 inch volume. Three versions of each Mars quadrangle are reproduced at an average scale of 1:10,000,000. Accompanying each set of three versions of each quadrangle is an index of pictures used in the compilation. In the past, the map makers have always strived to give their charts accurate positions, local information, and aesthetic appeal. It is unfortunate that these Mars charts were not printed in color as done with the original chart series.

The first version of each quadrangle is the controlled photomosaic from which final map products were derived. No other information is superposed on this version. The second version is an airbrushed shaded relief map based upon the photomosaic as well as a selection of special computer-enhanced pictures. The third version is again the shaded relief map, but with the addition of feature nomenclature, elevation contour lines, and sometimes albedo features interpreted from specially processed Mariner 9 pictures.

Albedo (brightness) renditions were not made for all charts because Viking images showed albedo patterns changing within a few weeks in certain areas. It is unfortunate that the mapping of albedo features was discontinued, because it's the seasonal phenomena that make martian science unique. The surface and near-surface changes are probably related to the topo-relief and seasonal wind regimes of Mars. Perhaps the lower resolution pictures of Mariner 9 or maps produced by planetary astronomers from red-light photos with similar seasons could have been substituted in order to complete the albedo overlay.

Five appendices follow the cartographic map section. A most necessary gazeteer of martian feature names (and their locations) used on Mars charts today is listed in Appendix A. A whole new scheme of topographic nomenclature was devised to extend and to be compatible with the existing classical Schiaparellian system. Nineteen classes of martian topographic features have now been recognized and given names. These topographic names are used as generic terms to the classical feature names originated by Schiaparelli and Antoniadi.

Although Mars has a diameter of only a little over half that of Earth, the total martian surface area to be mapped is slightly greater than that of Earth. Perhaps no historical documents measure more graphically our progressive understanding of the martian world than do the cartographic arts. Appendix B describes the map system design and related map products. The selection of the proper scales at which Mars was to be mapped, the projections used, and the division of the martian surface into 30 quadrangles were based on the resolution of the Mariner 9 pictures. This early planning of the cartography makes possible today the classification and the interpretation of the morphological features by the astrogeologists.

Contour mapping of surface elevations of Mars is of utmost importance to the study and understanding of past internal dynamics of the planet and to the present seasonal changes occurring today. Appendix C describes the several methods employed to determine elevation differences. The contour lines on most of the charts were compiled from Earth-based radar reflections and martian atmospheric pressure measurements made by Mariner 9 instruments, e.g., the ultraviolet spectrometer (UVS) or the infrared interferometer spectrometer (IRIS). In some cases stereoscopic TV pictures and radio occultation data were used.

It is obvious from the coverage maps shown in this section that neither the

UVS or the IRIS instruments obtained significant quantities of data north of the 30° to 40° parallels to produce accurate elevations. Further, only a few dozen data points from the Mariner 9 occultation experiment were available to define the surface elevations in the polar regions. Perhaps someday we can send to Mars a radar altimeter polar orbiting spacecraft to complete the job.

A limited, but adequate reference and bibliography list pertaining to martian cartography is given in Appendix E. A useful listing of recent Mars maps published by the U.S. Geological Survey that are available completes the volume.

The *Atlas of Mars* will be of use to professional and amateur planetary astronomers and to scientists in many fields of research. The five airbrush artists are to be commended for their strict attention to fine detail. Even armchair astronomers will find exploring the many spectacular and gigantic martian surface features a stimulating experience. Although the mapping of Mars is not complete in some areas, this *Atlas* is still the most accurate set of charts available to us today. *Charles F. Capen.*

Planets X and Pluto
William G. Hoyt
302 pages, hardcover, $17.50;
paperback, $9.50
University of Arizona Press (1980)

Although giving a good history of Uranus' and Neptune's discoveries, the most interesting and longest part of Hoyt's book details the people and events leading up to the discovery of Pluto just 50 years ago.

Handbook of Soviet Lunar and Planetary Exploration
Nicholas L. Johnson
262 pages, $25 (paperback), $35 (hardcover)
American Astronautical Society (1979)
[P.O. Box 28130, San Diego, CA 92128]

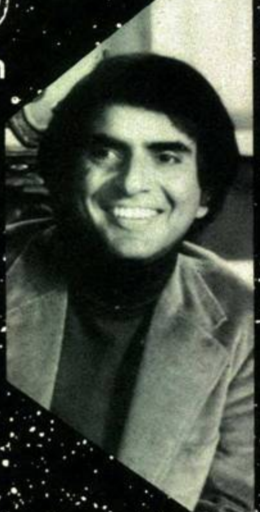
Space buffs will appreciate this. It offers a technical summary of all Soviet missions flown to the Moon, Mars, and Venus. Acknowledging the difficulties of obtaining facts on these missions, Johnson has tried to establish a baseline by consulting, where possible, the original Russian reports. There is a companion volume on their manned Earth orbital flights.

The Earth's Variable Rotation: geophysical causes and consequences
Kurt Lambeck
449 pages, hardcover, $77.50
Cambridge University Press (1980)

The spin of the planet is far from the simple matter it might appear. The fact that Earth isn't the nice solid ball of rock it seems produces some very interesting, if extraordinarily subtle, effects when looked at closely. Lambeck's book is aimed at the specialist reader and surveys areas of research that are currently being worked on.

The Pocket Guide to Astronomy
Patrick Moore
144 pages, plastic cover, $5.95
Simon and Schuster (1980)

Tall and narrow, this slender volume will indeed fit easily in your hip pocket. The contents survey adequately basic obervational astronomy at an amateur level (the Moon and planets, Sun, the constellations, nebulae, etc.), and cover in a more sketchy way the weird objects found at the frontiers of the science.



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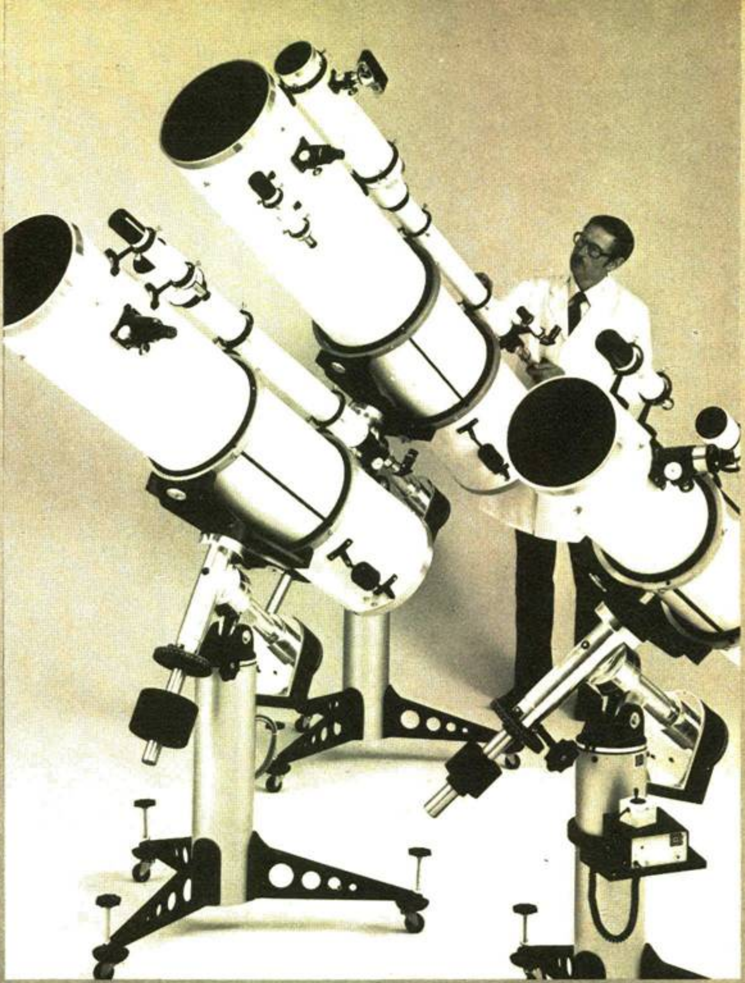

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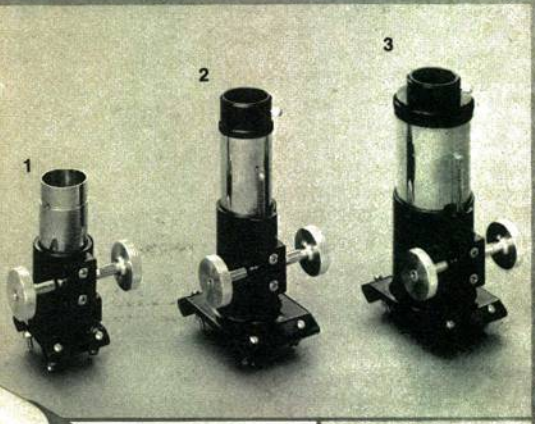

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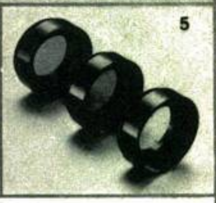
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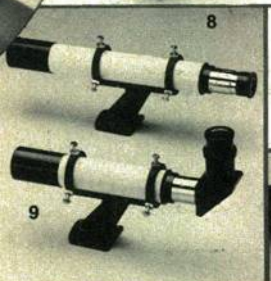

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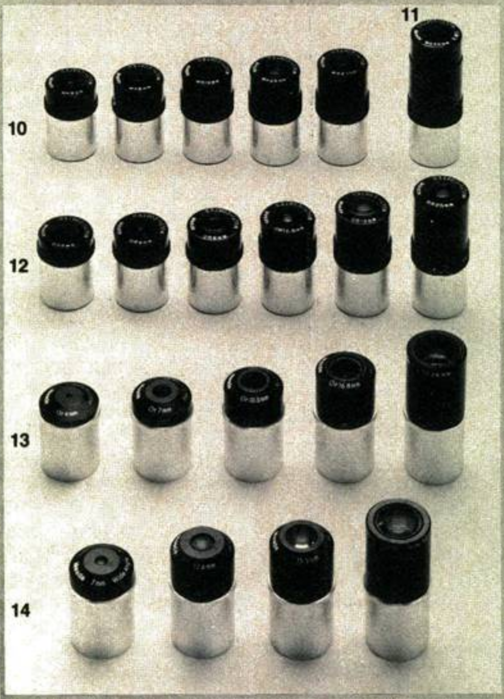

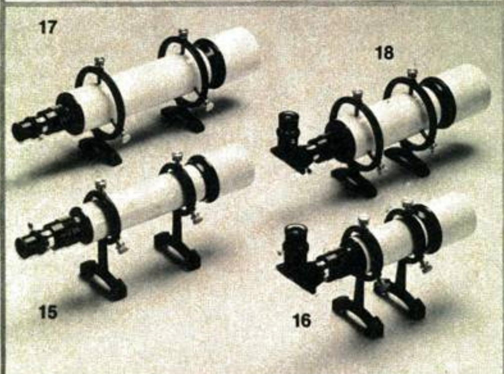

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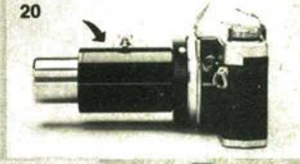
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equipment
atlas

how to buy a telescope for a child

This article is intended for the potential givers of telescopes, the parents, uncles, aunts, and grandparents of children who might receive a telescope as a gift this year. If you're a regular reader of ASTRONOMY, then astronomy is something you might like to share with a child, niece, nephew, or grandchild.

Or perhaps you're not a regular reader of ASTRONOMY. Maybe you're reading this because the (clever) child who might receive the gift has shown it to you. We'll help you sort through the complexities of buying a telescope (even though you probably don't know too much about telescopes) so that you can give a useful gift that will long be appreciated and used.

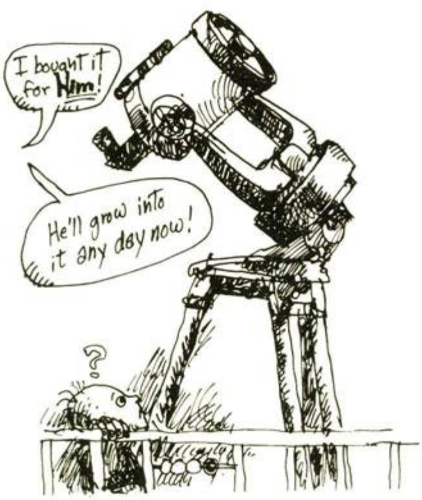
And, if you are the child, the potential giftee, you should probably be relatively modest in your expectations. Most adults have been children themselves, and are aware that your interests can shift as you grow, as theirs did. They don't want to see a telescope lie unused after a short but intense burst of enthusiasm ends. It's up to you to demonstrate the seriousness of your interest. Read all you can about astronomy, and be sure to learn the stars and constellations so you'll be ready for a telescope when the time comes.

Step One: the Child

How old is the child? Age counts, although not as much as you might think. A bright, interested eight year old can make more use of, enjoy more, and learn more with a telescope than a disinterested fourteen year old. The only real problems associated with the child's age are: 1) the weight and size that the child can lift or carry, and 2) how much money you're willing to spend on a child of that age.

How much does the child know? The best assurance you have that interest will last is the amount of effort he or she puts into learning about it. Has the child asked you questions? Does he/she find books and magazines about astronomy interesting and read them? Is the child interested in looking at the stars with you and learning their names and places? One warning: with the current craze about outer space, an enthusiasm for the stars of *Star Wars* may not extend to less glamorous real stars and planets.

How inventive is the child? Does he or she have manual skills or an aptitude for mechanical things? What about making or building things? A skillful child can probably use and take care of more complicated equipment.


I bought it for Him!
He'll grow into it any day now!
?

Are the parents supportive? Are they interested in natural history, science, and the world around them? Will they allow the child to stay up late to use the telescope?

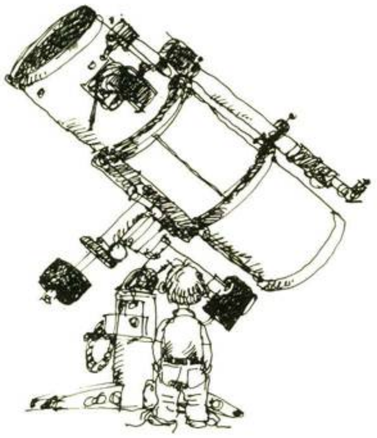
Would you like to build a telescope? A telescope makes a great "father/son" project if you have a modestly equipped workshop. Not only is building a telescope fun, but you'll get a bigger and better telescope for the money.

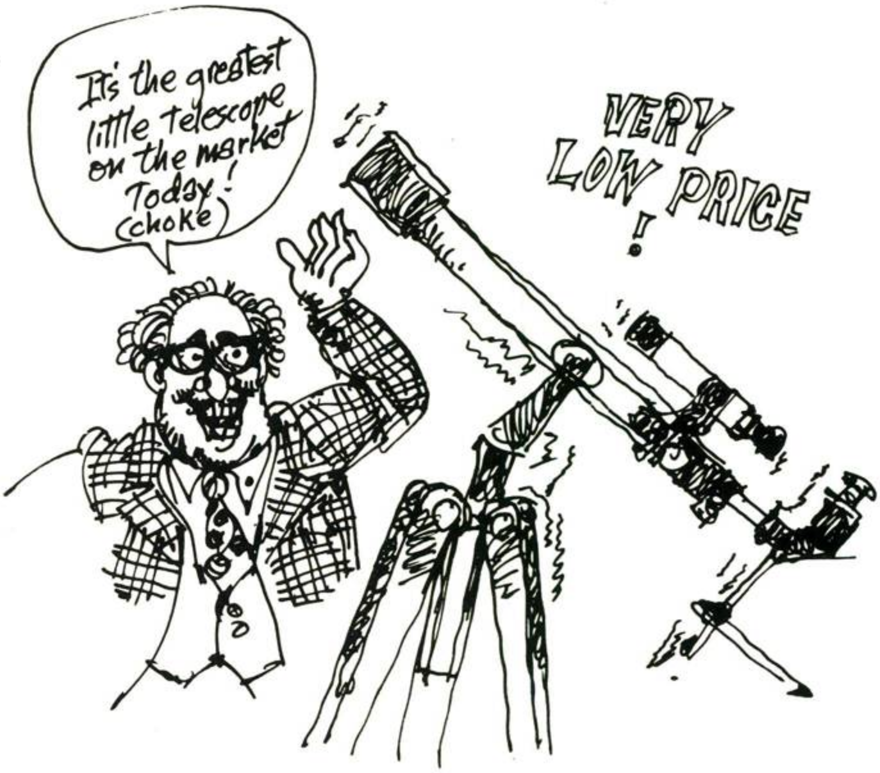
Who is going to use the telescope? Think about this carefully: Will the whole family share in the use of the telescope, or is it for one child's specific interest in astronomy? If it's for the whole family, and the interests of the family span a wide range (i.e., birdwatching, sports, shooting), then your choice will probably be a spotting scope supported on a camera tripod. If it's for a child, for astronomy, buy a good astronomical telescope.

Is the child ready for a telescope? Does he/she already know the stars and constellations? If not, the child is *really* not ready: instead of a telescope, buy a good introductory star book and wait until next year or a birthday to give the telescope.

Telescope Requirements

There are many different kinds of telescopes. What you really want is a telescope with a moderate aperture on a stable mounting — a telescope that's simple, durable, and easy to use. Your first impression, on looking at ads in ASTRONOMY and perhaps having visited a camera store or other retail outlet that sells them, is that telescopes are too expensive. For a child's first telescope, this is undoubtedly true. In looking in a toy store or two, you probably found a few that looked




It's the greatest little telescope on the market Today! (choke)
VERY LOW PRICE !

pretty shoddy, although the low price tag seemed attractive. You're not sure where to look next, and, for that matter, what to look for and ask when you find it. Here's what to look for:

Aperture Counts Most. More than anything else, the diameter (and quality) of the telescope's objective lens or mirror determines how a telescope will perform and what your child can see with it. Don't be misled by claims about magnification or "power" — find out the aperture of the telescope. Reflectors, for any given aperture, tend to be less expensive than either refractors or catadioptric telescopes.

The larger the main lens or mirror, the more light the telescope gathers and the sharper the image it delivers. As a general guideline, a reflector should have an aperture of at least 4 inches, and a refractor (which, please remember, is more expensive) should have an aperture of 2.4 inches, or 60 mm. A good 6-inch reflector is powerful enough to keep a serious teenage observer very happy. Because of their size and cost, only for "father/son" projects where you plan to build your own telescope should you consider a larger aperture for a "first."

Jupiter viewed thru Telescope with poor mounting

Stability is Essential. Next to aperture, nothing counts as much as the stability of the telescope's mounting. Imagine your own frustration in trying to find something in the sky with a telescope that just won't hold steady — then put yourself in the place of a child given a shaky telescope. Your interest would not endure for long, and you would rightly write off astronomy as a bad deal.

How can you recognize shakiness? The best diagnostic is to try out the telescope. You should be able to touch the tube, focus, remove and insert different eyepieces, and move the telescope from star to star without vibration or wobbliness. If you can't try a prospective telescope out, you can spot wobbly telescopes by their long, thin metal legs, tiny clamping screws, and extremely low prices. DO NOT GIVE A SHAKY TELESCOPE AS A GIFT. IT WILL NOT BE APPRECIATED.

the three types of telescope

Refractors have a special double lens at the front end to form an image at the rear of the scope. Because a single lens suffers from a defect called *chromatic aberration*, the lens is actually made of two different kinds of glass that correct and cancel this defect. Such lenses are called "achromatic," or "without color fringing." Small achromatic refractors are noted for their superb image quality.

Refractors are the type most familiar to the general public — the long skinny tube sitting on a tall tripod. Frequently the combination of length and poor mounting makes them unwieldy and difficult for a child to use.

The small beginner's refractors found in department stores have traditionally been Japanese-made, but goods from Japan have risen so dramatically in price that American-made telescopes are now frequently seen in camera shops and discount stores that sell telescopes.

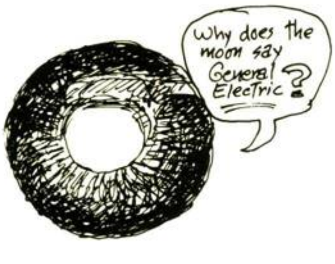
Reflectors use a curved mirror to form the image. The mirror is at the bottom of the top and directs the light back toward the open front end; then another small mirror bounces the light out the side of the tube to the eyepiece. Though reflectors may seem a bit strange at first, optical systems using mirrors are used on the world's largest telescopes.

There is more choice in the length of reflectors than refractors. The smallest 4-inch aperture reflectors are about 16 inches long; the longest are about 40 inches. The longer reflectors are generally better suited for viewing the Moon and planets from the city, the shorter ones for viewing stars, clusters, and nebulae from the country.

Reflectors provide the greatest aperture for the lowest price and are, by far, the type most commonly built at home. Most of the mirrors and complete reflecting telescopes for sale are American-made.

Catadioptrics combine lenses and mirrors for very compact stubby little telescopes. They are a relatively new addition to the marketplace. Although much more expensive per inch of aperture and far more mechanically delicate than either refractors or reflectors, for older children and adults they combine good portability and moderate aperture. Catadioptrics are also now being sold as telephoto lenses, and so are available in camera stores (which tend to discount) with increasing frequency.

Simplicity. Avoid gadget-laden telescopes. Gadgets tend to distract the child (and adults also) from looking through the telescope. They


Why does the moon say General Electric?

It's great for looking in windows!

telescopes for children

type	aperture	image	stability	useability	simplicity	durability	cost	brand names
refractor	2.4" f/10	B	D	C	C	D	$200+	Mayflower, Sears, Tasco
refractor	2.4" f/15	A	B	B	C	B	$450+	Meade, Pentax, Unitron
refractor	4" f/15	A	C	C	D	C	$600+	Tasco
reflector	3" f/10	C	D	C	C	D	$100+	Edmund, Gilbert
reflector	4" f/10	B	C	C	C	C	$150	Edmund, Tasco
reflector	4" f/10	A	B	B	B	B	$250+	Criterion, Edmund
reflector	4" f/4.5	B	A	A	A	B	$190	Edmund Astroscan
catadioptric	4" f/10	A	B	B	C	C	$500	Celestron, Meade, Quantum
catadioptric	5" f/10	A	B	B	C	C	$750	Celestron C-5
reflector	6" f/8	A	B	B	C	B	$300+	Criterion, Meade

Key to letter ratings: A = excellent; B = good; C = adequate; D = poor for children.

Note: The comments in this table do not constitute an endorsement or recommendation for any type or brand name of telescope, nor do they necessarily represent the specifications of any telescope currently produced or available.

place attention on the instrument and not on its function. Small parts also tend to get lost or damaged, potentially disabling the telescope and, with kids, complexity can cause loss of interest.

Durability. Look for a well-built telescope. Nobody likes to think it, but with pre-teen kids, the telescope is sooner or later going to be knocked over or fall on the ground. A well-built telescope, with tough, heavy-duty parts, will survive. Ask yourself, as you look at the telescope, whether or not you think it will last. If you have any doubts, keep on looking. Nobody likes a flimsy telescope.

Spin the Bottle!

Ease of Use. A telescope for a child, especially a younger one, ought to be simple. Setting up and using an equatorial mounting is beyond the abilities of many younger children and many adults. A well-made alt-azimuth mount is easier to figure out, but a poorly-made one can be a mechanical terror. The best bet, if you're not terribly familiar with telescopes yourself, is to try the telescope without referring to the manual. If you can figure out how it works without instructions, then it's probably suitable for a kid. (Minor warning: check the manual. It should be readable and comprehensible.)

The easiest telescopes to use don't require diddling with knobs and clamping screws each time you go to look at a new object. If a telescope does have knobs and clamps, they should be large and easy to operate by feel in the dark.

The "Power" Trap

Don't be misled or impressed by claims of "power," especially if, in the advertisement, you see stars or zoom-lines around "600x!" This is a sure give-away that the telescope is capable of no such "power."

There are three kinds of "power" that count: light-gathering power, magnification, and resolving power.

Light-gathering power is simply the increase in the amount of light the telescope gathers over what your eye can alone. It depends strictly on the aperture of the telescope, and is the same for all telescopes of the same aperture. A telescope with a 60 millimeter aperture gathers 85 times more light, and a 100 millimeter (4-inch) gathers 200 times more light than your eye. Aperture counts most.

Magnification is what most people and most advertisements mean when they say "power," and is vastly overrated because claims of great power sell cheap telescopes. Be conservative and ignore all claims about "power." Since magnification depends on the eyepiece used in the telescope as well as the focal length of the telescope itself, by changing eyepieces, you can change magnification.

Generally, it's nice to have one for low power (say 15 to 30x), one for middle powers (such as 40 to 60x), and one for high power. For practical purposes, 60 mm to 100 mm telescopes can't often be used at much over 100 to 150x. The maximum useful magnification depends on the aperture.

(Just in case you've never used a telescope yourself, the moons of Jupiter can easily be seen at 15x, the rings of Saturn pop out at 30x, the Moon fills the field at 60x, and most small-telescope double stars can easily be split at 120x. Don't overlook the advantages of relatively low power: it's much easier to find objects in the sky at low magnification.)

Finally, there's resolving power. Resolving power determines the amount of detail you can see, and is limited by the fundamental nature of light. With good optics, resolving power depends only on the telescope's aperture. As a reliable rule of thumb, small telescopes that are well-made mechanically are usually optically perfect — and can deliver resolution to the theoretical limit. It's much easier to skimp, if you're in the business of manufacturing cheap telescopes, on the mechanical design than on the optical system.

CITY SKIES.....
COUNTRY ..

The Accessory Trap

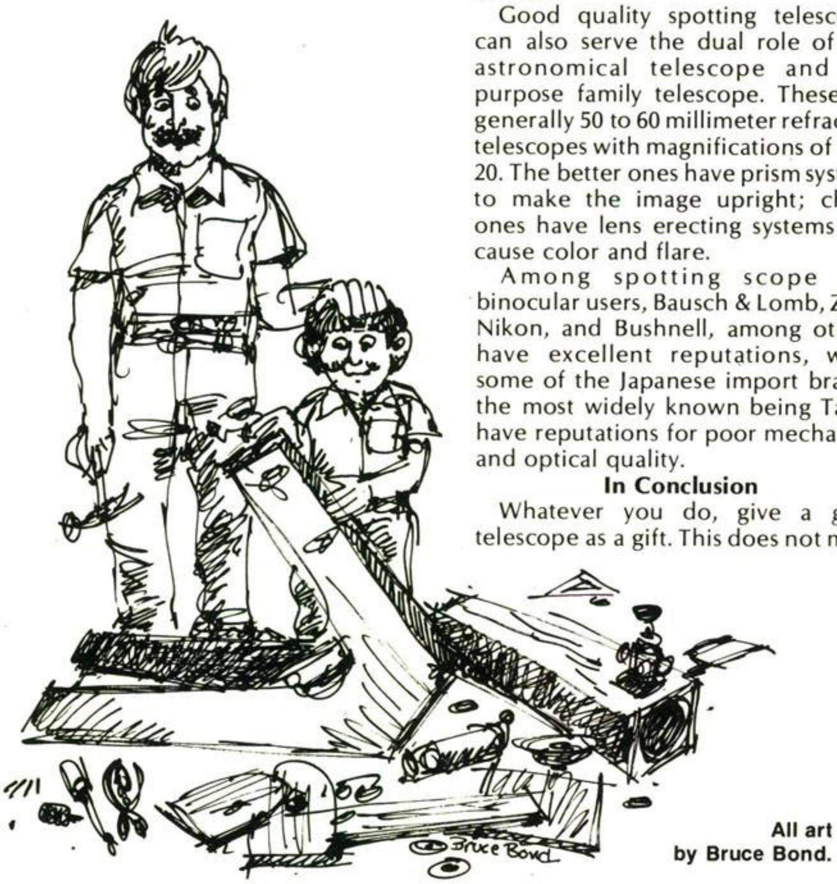
Over-accessorized telescopes are often under-utilized. Accessories distract a child from the basic function of the telescope, which is looking and observing what he/she sees. 98% of the time a telescope is in use, only the finder scope, the eyepieces, and, if it's a refractor or catadioptric, the star diagonal are used. With telescopes, as with many other hobbies, dealers would like to sell you a "fully-loaded" piece of equipment. Don't fall for it: if you buy what seems like a stripped-down model — without all the "extras" — you'll really be doing the child a service. If you later want more gadgets, buy them as the needs arise, when you want them, for specific purposes. (This solves the next-year's-present and birthday dilemma, too.)

Me — Build a Telescope?

Why not? Building a telescope with a child is an excellent way to spend time together. You'll both get to know the telescope literally inside and out, and you'll save a lot of money. ASTRONOMY has published several designs suitable for building in a home workshop equipped with simple hand tools:

- A 4-inch f/10 reflector on an equatorial mounting (October 1978 issue) that would today cost about $90 to build. The optics are purchased for about $35, the eyepiece holder for about $25, and the rest all homemade. The tube is square, made of ¼" plywood; the mounting is made of pipe and heavier plywood. It's an elegant and straightforward shop project. This telescope is suitable in size and weight for kids from 10 to 14.
- Several different designs for 6-inch f/8 reflectors from the "How to Build a 6-inch Telescope" series that ran in the April, May, August, September 1977 and the January 1978 issues. For about $200, mainly depending on how much you buy and how much you build, you can have a truly "lifetime" telescope. Good for kids from 12 right through adults.
- For a more ambitious project, the 10-inch Dobsonian telescope (June, July and August 1980) can't be beat. It's a really large aperture telescope, ideal for visual observing, that costs between $200 and $350. For kids who are handy with tools, it's excellent for those about 14 years or older. Give the optics (think ahead — delivery times run pretty long) as a gift, and then let him/her build the rest, with your help if necessary.

All of these telescopes work well and, properly built, meet the criteria of being easy to use and durable, and fit within the family budget.



All art by Bruce Bond.

Alternatives

Don't forget some of the alternatives to a telescope. A good pair of 7 x 35 or 7 x 50 binoculars can serve as a useful introduction to astronomy, and, if astronomy pales as the child's interests change, binoculars have lots of other uses. Binoculars are not, in themselves, sufficient to nourish a growing interest in observational astronomy, but the money spent on a good pair will not be wasted.

Good quality spotting telescopes can also serve the dual role of first astronomical telescope and all-purpose family telescope. These are generally 50 to 60 millimeter refracting telescopes with magnifications of 15 to 20. The better ones have prism systems to make the image upright; cheap ones have lens erecting systems that cause color and flare.

Among spotting scope and binocular users, Bausch & Lomb, Zeiss, Nikon, and Bushnell, among others, have excellent reputations, while some of the Japanese import brands, the most widely known being Tasco, have reputations for poor mechanical and optical quality.

In Conclusion

Whatever you do, give a *good* telescope as a gift. This does not mean the most expensive, or the fanciest, or the one with the most attachments. It does mean a telescope that can stand up to wear and tear, moderate mishandling, the wrath of younger brothers — a telescope that's easy to use, fun to look through, the one that captures a child's imagination.

But don't think that because it's for a child you can skimp on quality. Many ASTRONOMY readers now in their twenties or thirties have found their teenage interest in astronomy rekindled only after years of disappointment from hopelessly bad Christmas telescopes. There is no surer way to make an unsuspecting kid lose his or her interest in astronomy than a telescope that just doesn't work.

Take the trouble to try out a few telescopes yourself, or involve the child directly in the decision. Shop around a bit, and be critical. If you're not happy with the telescopes you see, if good performance and more-than-just-adequate stability are lacking, don't expect a child to be satisfied. And don't treat a telescope as just another toy.

— *Richard Berry*

books for kids

Look to the Night Sky by Seymour Simon, Puffinbooks, $2.95.

> "An introduction to skywatching, finding the constellations, observing the Moon, and using a telescope." (Beginner to intermediate)

The Sky Observer's Guide by Mayall, Mayall, and Wyckoff, Golden Press, $1.95.

> "Lots of illustrations and information about looking at the sky and using a telescope." (Intermediate)

Whitney's Star Finder by Charles Whitney, Alfred Knopf, $5.95.

> "Lots about astronomy, a field guide to the sky. Includes a plastic planisphere-type star finder." (Intermediate plus)

photography
in
astronomy

get the most from your deep-sky negatives

by
Lee C. Coombs

As anyone who's tried will tell you, astrophotography can be a very demanding avocation, and that of deep-sky objects may be the hardest of all. Behind every fine slide or print lies a long chain of effort. Learning how to get the most from those negatives you've invested hours and hours in is only good sense, but many neophytes wonder how to get going. To give them a hand, here are some reliable techniques I've used for nebulae and other deep-sky objects.

Develop Carefully

The best films at present for long exposures on faint objects are Kodak's 103a series and 2415 Technical Pan. To get the most out of the 103a and Technical Pan films, the recommended developer is D-19. Four to four-and-a-half minutes souping at 68° F will yield high-contrast negatives.

Another choice, developed specifically for the 103a emulsions, is MWP-2. Order the developer from Clayton Chemical Company, 3867 Grandview Blvd., Los Angeles, CA 90066. It comes as two packages of powder and a vial of liquid to make 5 gallons of developer, the minimum quantity you can order. Write for prices.

I divide the three components into 10 equal batches so that only 2 quarts of developer need be prepared at one time. Using MWP-2 results in about one stop increase in film speed with only a minor increase in grain. The recommended development time is between 7 and 12 minutes at 68° F. I've found 9 minutes a good compromise.

Lower contrast developers such as D-76, HC 110, Acufine, and Microdol-X can be used to bring out detail in the brighter regions of various nebulae; but you'll lose some faint detail along with film speed. In general, I prefer to get high contrast negatives and take advantage of the full film speed, and then use appropriate printing techniques to bring out faint or overexposed details.

Developing 103a films is very similar to developing most other black and white films, but with the difference that the antihalation backing must be removed during the procedure. (With ordinary films, it dissolves in the processing.) I find that a stop bath of 3 changes of water followed by agitation removes most of the backing. Acid stop baths won't do the trick. The last traces of backing can be removed after the film is fully developed and washed by swabbing the back of the film with a photographic sponge soaked in Kodak Photo-flo. This minimizes the chances for damaging goof-ups during handling.

Helix Nebula

The 103a emulsions are very sensitive to changes in temperature during development and washing, so take care to assure that all solutions and wash water do not vary by more than 2° F. Subjecting the emulsion to temperature changes greater than this will net you a noticeable increase in graininess.

The Art of Printing

Obtaining the best print from a given negative really amounts to an art. A print that shows as much detail as possible on the negative takes time and patience. There are some darkroom tricks that'll make a so-so print into a truly breathtaking one, but the proper technique depends on the quality of the negative — most importantly, the contrast between the object and the sky background.

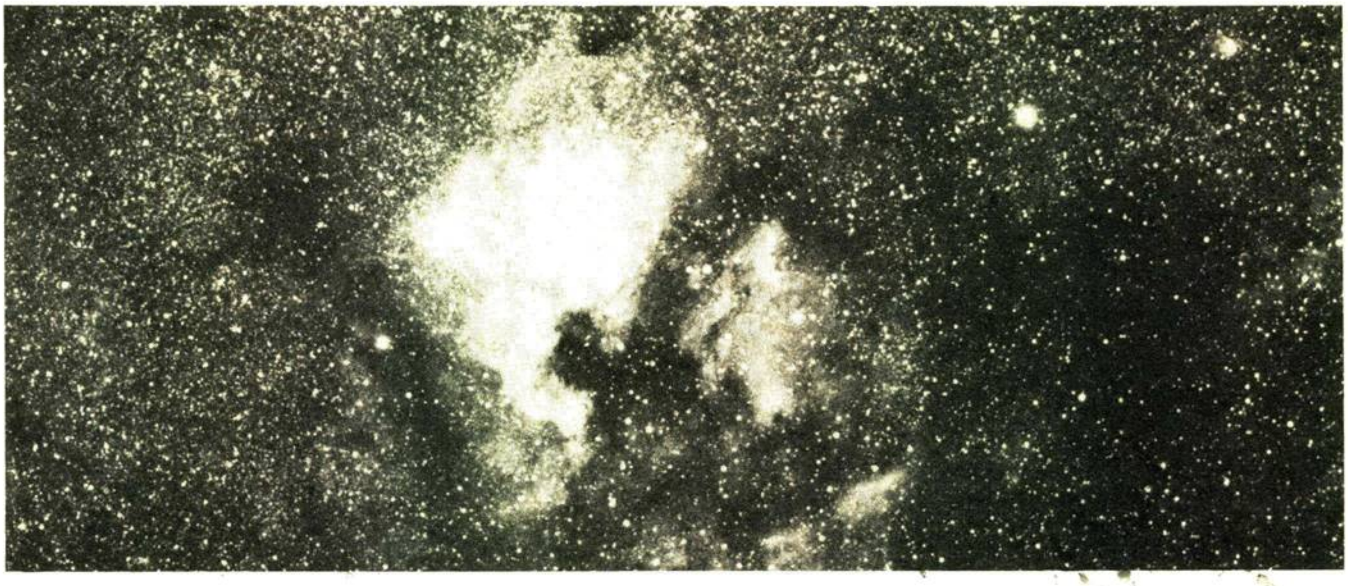
Most images of nebular and other deep-sky objects come up significantly enhanced if you print them on the higher contrast paper such as grades 4, 5, or 6. These exaggerate faint or underexposed areas by providing additional contrast between the object and the background, a characteristic that brings out details otherwise lost on normal grade paper.

But along with the enhancement of the object, expect to see grain becoming more apparent, particularly with the 103a emulsions. To a certain extent it's unavoidable, and keeping the enlargements to 8x or less will keep the grain from being too objectionable in the final print.

When you use high contrast papers, you'll often find dodging and burning necessary to bring out details in the well-exposed regions and/or retain detail in the lighter areas. Dodging is when you hold back exposure in an underexposed part of a negative; in burning you add it to the dense parts. Both take practice, particularly in the highest contrast grades, but the final result can be a more uniform and better detailed print.

Astrophotographers faced with light pollution commonly get low contrast and underexposed negatives because sky fogging places severe limits on exposure times. With such negatives,

Dramatic improvements come from integration prints! At bottom is a print on grade 5 paper from a single negative: it's grainy and lacks detail. At top we see the results of printing four separate negatives into one print: the grain no longer dominates and additional stars and wisps appear. All photos by the author.



The North America Nebula (NGC-7000) in Cygnus is a subject that benefits greatly from negative enhancement. Start with a red-light exposure on 103a-E film with a Wratten 25 filter, copy once onto a high contrast film, and recopy to make a negative which will show the nebula standing out from the background stars.

high contrast papers don't often yield reasonable prints. To salvage what you can, try the following technique. It's relatively simple and the boost in contrast is amazing.

Enhancing a Weak Negative

First, place the negative to be enhanced in the enlarger. Take a camera, load it with Kodak High Contrast Copy, Kodak 2415 Technical Pan (originally SO-115), or some other high contrast, fine grain film, and remove the lens. Place the camera under the enlarger so that the negative can be projected into the camera body.

When you project the negative, keep the amount of enlargement close to or right on 1:1. After obtaining an exposure time via the camera's meter, take a series of bracketed exposures using the camera shutter.

Develop the film as recommended and choose one of the positive copies that is slightly underexposed. (You do this to make sure all detail is retained.) Then recopy this positive in the same way as before to make an *internegative*. Since a substantial boost in contrast happens in the first step, the second copy should be made with a fine grain, wide-latitude film like Kodak Panatomic-X. If you really want cranked-up contrast, make the copy using the same film employed in the first step.

If you've done it right, the internegative can be printed on normal grade paper. For extreme contrast, make the print on higher grades of paper. The photographs of the Rosette Nebula show what this technique can do. The original negative printed on grade 5 paper doesn't begin to show the detail obtained from the high contrast internegative printed on grade 3.

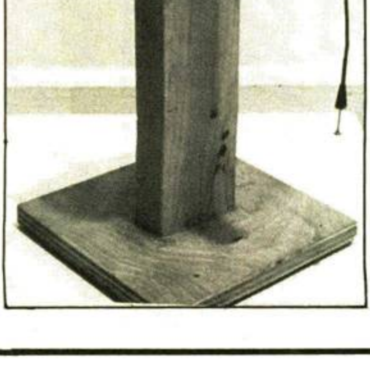
An alternative way is to make a slightly underexposed 8 x 10 print on high contrast paper and then rephotograph it under even illumination. You'll end up with results similar to the film method. The drawbacks to both ways are that negative defects and grain get enhanced, too.

Fighting Down Grain

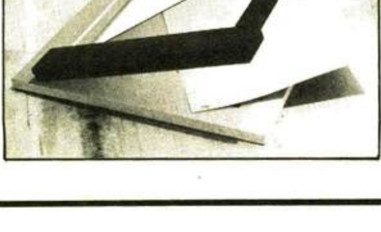
If you can make negatives with good contrast and detail, then grain may become your next concern. This is particularly true if you wish enlargements of 8x or greater from those 103a negatives. Grain can be subdued a bit by using normal or low contrast grades of enlarging paper though, of course, you'll say goodbye to a lot of faint detail.

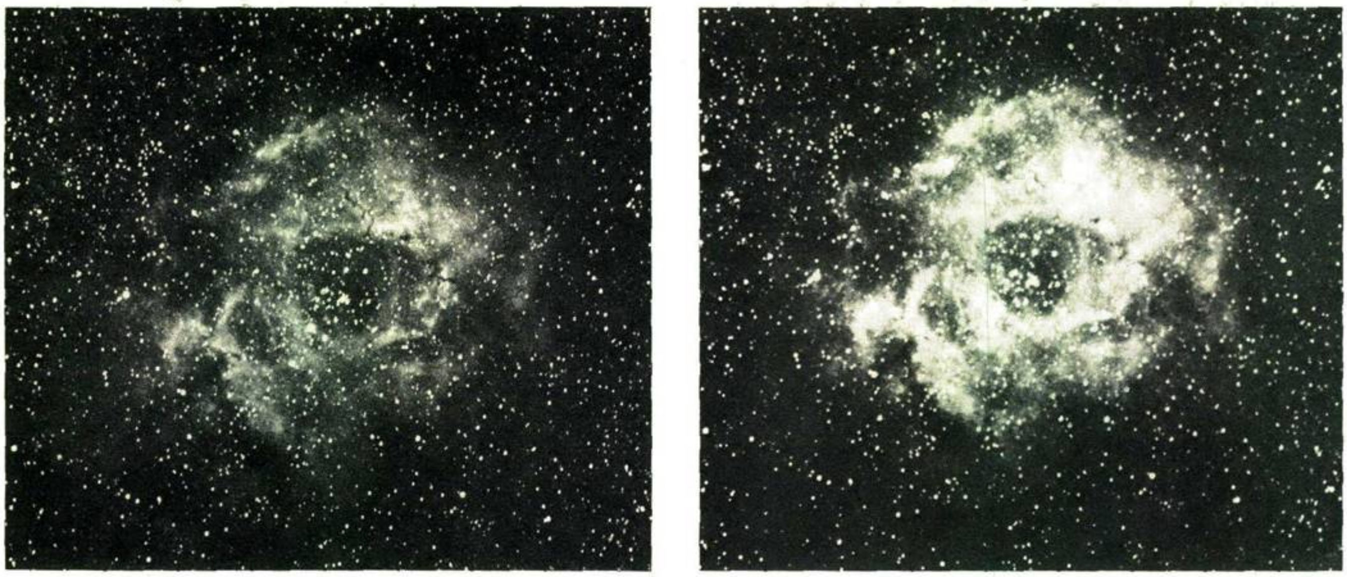
One method that takes advantage of the speed and high contrast of the spectroscopic films and still yields high-definition, fine-grain enlargements is integration printing. The process requires a series of identical negatives of an object, each of which is capable of producing a quality print by itself.

The method involves dividing the printing time between a series of identical negatives. Typically, 3 to 5 are used in making the final print. As a result, the random grain pattern of each negative averages out. Relatively simple, the technique produces very striking results. Even enlargements



Tools of the trade: Below is the integration print frame with lift-up mask (dark parts are wood stiffeners) and print paper. Left: The stand which holds the camera below the enlarger when recopying negatives for contrast.





The benefits of negative enhancement show clearly with this photo of the Rosette Nebula in Monoceros. Above left you see a straight print on grade 5 paper made from the original negative. Compare this with the print (directly above) made from a Kodak High Contrast Copy film internegative — printed on grade 3 paper!

ranging from 8x to 15x are possible while retaining both good contrast and grain characteristics. Compare the two photos of the Horsehead Nebula in Orion: one used a single negative; the other is a 4-negative integration print.

To begin you will need three or four well-matched negatives of the same object. Try to take them all on the same night so that the variables (seeing, transparency, etc.) are constant between them.

To get each negative printed exactly on top of the others, you'll have to make a simple registration jig. Tape the top edge of a piece of cardboard, such as photo mounting board, to the printing easel or the enlarger base. Be sure the cardboard is opaque and larger in both dimensions than the printing paper you intend to use. The tape allows you to flip the cardboard mask back and expose the enlarging paper positioned below it. If the cardboard mask doesn't lie flat on the baseboard, glue some wood strips along the front and side edges.

Flip the mask out of the way and make a test strip using one of the negatives. Each negative should be printed somewhere between 6 and 10 seconds. For three negatives, this would correspond to a total exposure time between 18 and 30 seconds. (You'll have to adjust the enlarger lens aperture until you get the right amount of light for a 30 second print.) Though tempting, shorter exposure times make it extremely difficult to compensate accurately for under or over-exposure, or to allow for dodging and burning.

Let's suppose, for example, that we have three negatives and the test strip indicates a total exposure time of 30 seconds. Unfortunately, due to reciprocity failure, running the three negatives at 10 seconds each would result in an undertimed print. As a starting point, increase the exposure of the first negative by 20% and that of subsequent ones by 10%. So, in this case start with exposures of 12, 11, and 11 seconds. Use high contrast grades of paper.

Carefully focus the negative on the baseboard or easel. When it's correct, leave the focus and height adjustments alone until all printing steps are complete. With cardboard mask flipped into place, carefully mark three or four widely-spaced stars on the surface of the mask. Subsequent negatives are positioned by moving the baseboard, easel, or negative itself (whichever's easiest) until the same reference stars line up perfectly at their index marks.

Turn the enlarger off and fix a piece of enlarging paper to the baseboard or easel with doubled-over masking tape. Close the register jig over the paper, and then turn on the enlarger to check the positioning of the negative. Stop the lens down to the predetermined setting and turn the enlarger off.

Lift the mask and make the first exposure (12 seconds in our example). Then turn off the enlarger, close down the mask, and place the second negative in the carrier. Move the jig until the reference stars are in perfect registration. Setting the lens wide open may help in registering the negative, but watch out you don't fog the paper below the mask. Stop the lens back down, turn off the enlarger, flip aside the mask, and turn it back on again to expose the second negative (11 seconds in our example). Repeat the procedure for the third negative.

Develop and examine your print. To catch all possible detail, properly exposed astro-negatives should exhibit a dark gray sky, not a jet black one. Prints with a black sky have unrecorded or suppressed faint details, so vary the printing times by 1 or 2 seconds per negative until an optimum print comes out. Of course, each exposure step can be burned or dodged as needed.

It sounds like a lot of bother if you've never tried it, but integration printing leads to high quality enlargements for a little darkroom effort. Once you get hooked, you may wish to construct a special enlarging easel to hold the paper without tape for a bordered print. I built just such an easel using scrap wood and a piece of photo mounting board for less than a dollar. The additional time spent at the telescope acquiring multiple negatives and in the darkroom doing printing, is more than repaid when you get a great-looking print.

Don't stop before you have a good print — experiment with these techniques. Often one print doesn't show the whole treasure-trove of detail present in a negative. Most black and white negatives respond very well if you take the same time and care to print it as you did with the original exposure. You'll find the results unquestionably worth the effort.

Lee is a professor of chemistry at California Polytechnic State University in San Luis Obispo. Astronomy has been his hobby for over 20 years, with astrophotography catching his interest 5 years ago.

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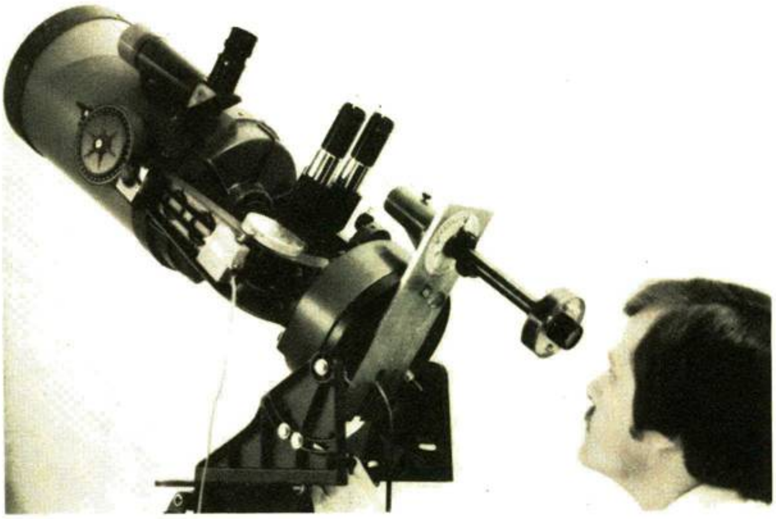

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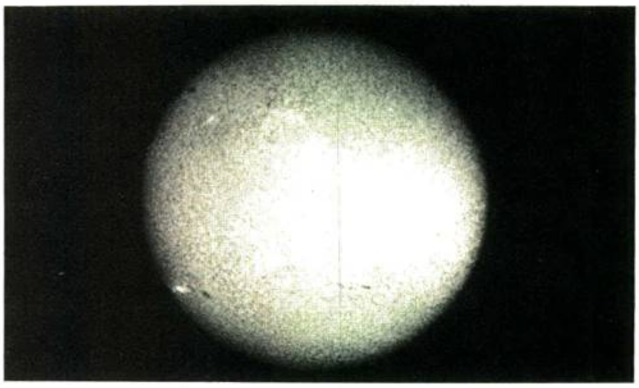

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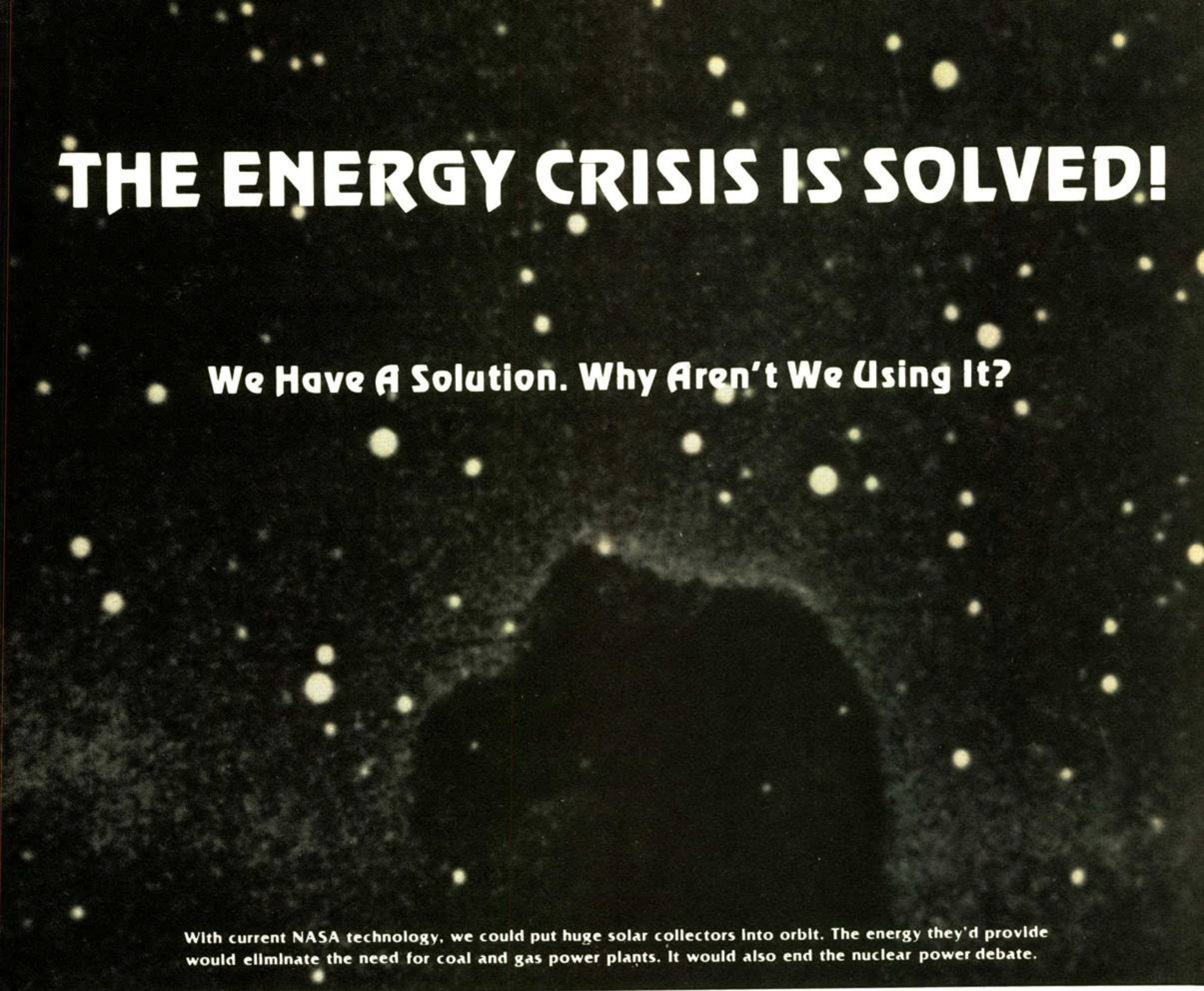

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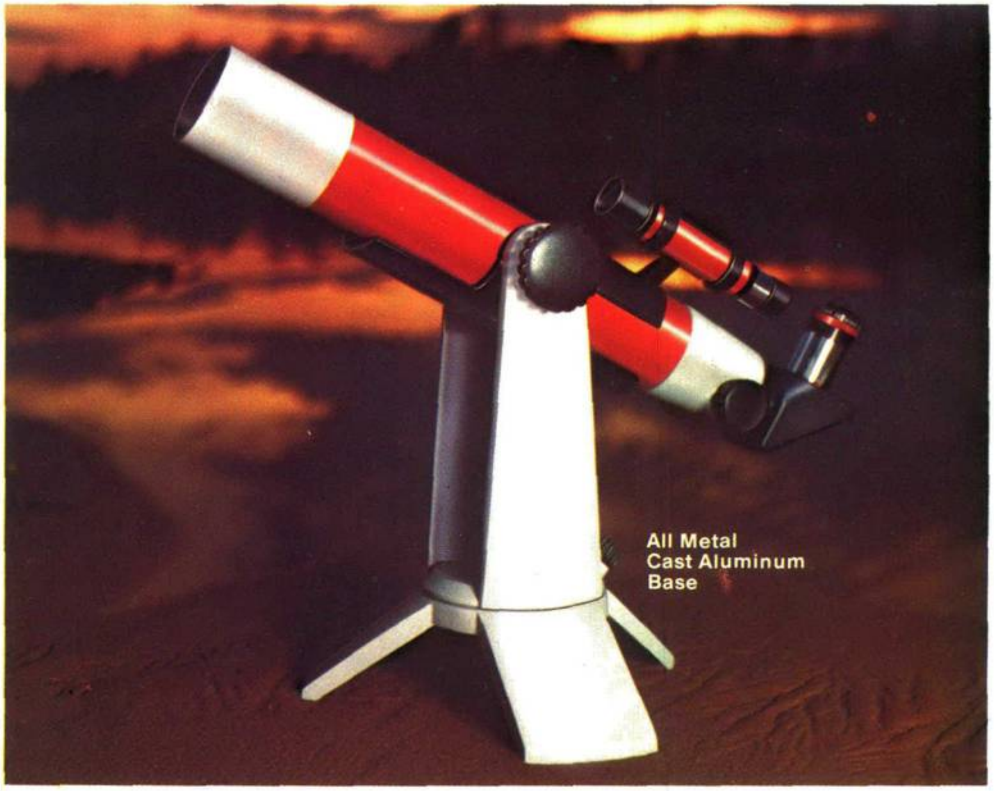

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AstroNews

Worldwide Study of Solar Flares Pays Off

An intensive worldwide effort, planned for more than two years, has resulted in an accumulation of scientific data that solar scientists believe will provide them with the clearest knowledge of solar flares ever produced.

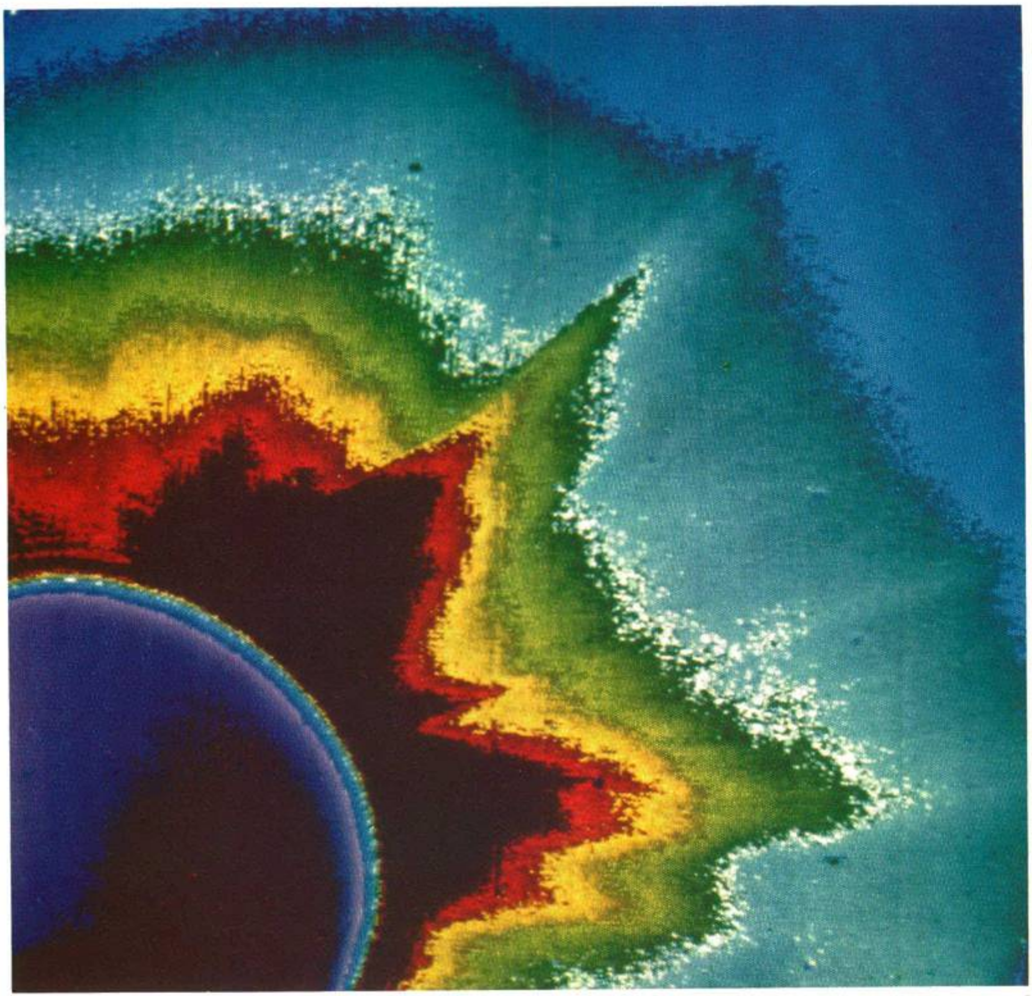
The effort, known as a flare buildup study, involved experiments aboard NASA's orbiting Solar Maximum Mission (SMM) spacecraft and a network of the world's most highly sophisticated and powerful ground observatories. It was coordinated by Dr. Paul Simon of the Observatoire de Paris, France, as part of the International Solar Maximum Year.

The purpose of the study was to obtain as many scientific measurements from as many different sources as possible during a six-week period in 1980 — a year when the Sun is at the peak of its eleven-year cycle of activity. The dates were established two years ago, when the scientific community gambled that the second two weeks of May and the month of June would be an active period on the Sun.

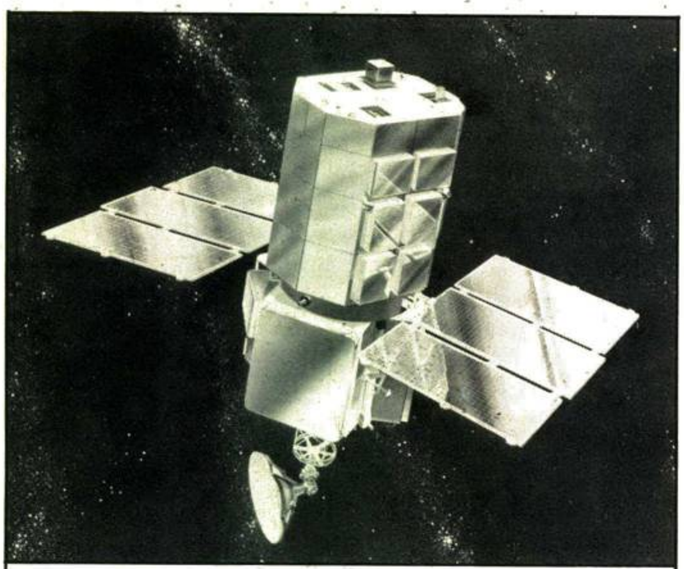
During the early stages of the study, the scientists were able to make some significant observations. Then on June 24, on the basis of predictions of worldwide forecast services, observatories in 18 nations and all flare instruments aboard the spacecraft focused on an active region of the Sun identified as Region 2522. On June 28 and June 29, the Sun produced two major flares out of Region 2522.

Significantly:

- They were captured by all seven flare instruments aboard the spacecraft, marking the first time all the instruments had made measurements simultaneously of the same flare since the spacecraft was put into its 357-mile (575-kilometer) high orbit last February 14.
- Leading world observatories — including the Solar Radio Observatory in Culgoora, Australia; Sacramento Peak Observatory and the Very Large Array Radio Telescope in New Mexico; Itapetinza Observatory in Brazil; the Owens Valley Radio Interferometer in California; and the Mauna Loa Observatory in Hawaii — also obtained information from the flares. The flares occurred during daylight hours for observatories in the United States, South America, and Australia.
- The observation was the first in which scientists could trace material ejected from a flare from the Sun's edge into the outer solar atmosphere. Through the collaborative use of the instruments on the spacecraft with the Culgoora radioheliograph in Australia, the data are expected to provide new understanding of the intensity of the magnetic field and the electron density in the matter blown from the flare.
- The two flares were what scientists call homologous flares, which means they were nearly identical in structure, position, and character. Explanations for such a



This view of the Sun's outer atmosphere, known as the corona, was made by a special telescope aboard NASA's Solar Maximum Mission spacecraft and artificially enhanced by a computer imaging process. The different colors indicate differences in electron density in the corona, where temperatures rise as high as four million degrees Fahrenheit. The dark disk, a part of the telescope, blocks the intense light of the Sun's surface, permitting scientists to view the corona from 300,000 miles above the surface to about two million miles out. Ejections from the Sun's surface expel as much as a billion tons of gas at speeds of approximately a million miles an hour. Using pictures such as these in combination with other data, SMM scientists are studying the coronal evolution and other features of active solar regions in an effort to determine the mechanism which triggers a solar flare. Photograph courtesy of NASA/Goddard Space Flight Center.



NASA's Solar Maximum Mission spacecraft is seen in an artist's conception above. Launched into orbit on February 14, 1980, the spacecraft has been designed for a minimum operational lifetime of one year. At the end of its mission it is to be retrieved by the Space Shuttle. NASA/Goddard Space Flight Center photograph.

concurrence vary from sheer coincidence to the theory that the magnetic field reconfigures itself after one flare has fired to the same configuration it had prior to the flare, with the second instability almost identical with the first. If the similarities are not accidental, homologous flares could provide important clues concerning the physical mechanism operating at the surface of the Sun to control the magnetic structure in an active region.

The degree of uniformity from flare to flare will prove to be very significant in resolving the puzzle of homologous flares, and the comprehensive coverage by the spacecraft and the ground observatories should allow scientists to determine if homologous flares are accidental or not.

Previously, scientists had been able to document a flare with as many as six of the flare instruments aboard the Solar Maximum Mission spacecraft. In most of these previous cases, however, the flares being observed erupted on the face rather than on the rim of the Sun. Eruptions on the face of the Sun preclude the effective use of the coronograph/polarimeter, which can picture only those activities that take place in the corona (outer atmosphere) of the Sun.

Because of the concentration on Region 2522 and its movement to the rim of the Sun, the coronograph/polarimeter was able to zero in on the atmosphere above the two flares, bringing all of the flare instruments on board the spacecraft to bear on those flares. The coronograph/polarimeter was designed and built by the High Altitude Observatory in Boulder, Colorado.

Other instruments aboard the spacecraft taking key measurements during the eruptions were the ultraviolet spectrometer/ polarimeter, which studies ultraviolet emissions, and the hard X-ray imaging spectrometer, which images the high energy radiation produced by atomic particles accelerated in flares to speeds very close to the speed of light.

It is from the solar magnetic fields that flares draw their awesome energy. Measurements have shown that the Sun's magnetic fields are of tremendous power and extend over areas many times as large as the Earth. Improved techniques for measuring solar magnetic fields are a relatively recent development in solar physics. Until the early 1900s, astronomers had only speculated that the Sun, like the Earth, had magnetic fields. In 1908, with the advent of the spectroheliograph and improved telescopes, the first measurements of the Sun's magnetic activity were made at the Mt. Wilson Solar Observatory.

Now the observations from the Solar Maximum Mission, in conjunction with coordinated ground-based observations, are helping to establish the theory that solar flares are caused by the collision of powerful magnetic fields on the Sun. According to SMM investigators, "The data strongly suggest that a low-flying magnetic loop filled with hot gas becomes excited, rises in altitude, and collides with a higher-flying magnetic arch. It is the collision of these two magnetic arches which, it now appears, will initiate a flare.

"If our preliminary analysis holds up," the scientists said, "it is a most significant confirmation of one of the theoretically proposed flare-triggering mechanisms."

With the new knowledge gained by the SMM and other observations during the current Solar Maximum Year, predictions of flare occurrences might become more reliable. Improved predictability would heighten forecasts of increased solar output on the Sun, which disrupts communications and possibly affects climate and weather conditions on Earth.

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Amateur Space Telescope

The Space Telescope, a 96-inch (2.4 meter) instrument scheduled to be placed in Earth orbit by the Space Shuttle sometime in late 1983 or 1984, is expected to revolutionize observational astronomy. Freed from the limitations imposed on even the highest-altitude Earthbound observatories by our thick, churning atmosphere, the orbiting telescope will be able to make observations of unprecedented value.

Plans are now being made to place a second telescope in space — but this one would be an amateur instrument. The Independent Space Research Group (ISRG) Space Telescope, otherwise known as the Amateur Space Telescope (AST), had its beginnings in early 1979, when a few students at Rensselaer Polytechnic Institute (RPI) realized that a small astronomical satellite could be built using mostly off-the-shelf parts, and then launched onboard one of the inexpensive launch options such as the Shuttle Get-Away Specials.

Amateur radio enthusiasts have been sending up inexpensive Ham communications satellites for years, and the students felt that recent advances in the commercial electronics and computer industries would make amateur astronomical satellites possible as well.

The primary goal of the project is the construction of an astronomical satellite carrying an 18-inch Ritchey-Cretien telescope. This device is tentatively scheduled to be launched in late 1984 as a piggyback payload on an Ariane booster (the new launch vehicle of the European Space Agency). A preliminary goal is the construction of a "Test Satellite" for a free piggyback launch in 1982 aboard a conventional U.S. rocket, and possibly a second, slightly more advanced Test Satellite for launch in 1983.

The proposed AST will weigh almost 200 pounds, being roughly cylindrical in shape, 19.75 inches in diameter, about 73 inches from end to end, and occupying a volume of about 9 cubic feet. The design was originally meant to collapse into a Get-Away Special standard container, but that launch option probably won't be used.

A solid state CID TV camera will be used for imaging in

AstroNews

the near ultraviolet, visible, and near infrared regions of the spectrum. These cameras can be exposed to light for long periods of time to achieve a time-exposure effect — with a little help from an onboard microprocessor. Also included onboard will be a small spectrograph and two or three photometers covering the far ultraviolet and possibly more of the infrared region. Attitude control and fine pointing will be handled by flywheels. Power will be supplied by solar panels, which will keep a battery pack charged. The transmitter (which may be supplied by AMSAT, the non-profit corporation which handles the amateur radio "Oscar" satellites) will have a few watts output. The microprocessor will control everything and turn commands into action.

A worldwide network of existing Ham stations will be organized to control the satellite and receive data from it. In addition, anyone with a few hundred dollars worth of equipment will be able to get pictures and data directly from the device.

The AST will be used as a general access instrument for both scientific and educational uses, and will be made available to any amateurs, professionals, astronomical organizations, or educational institutions with worthwhile project proposals. The Test Satellites will probably be built under the auspices of RPI, but the more expensive — and much more complex — Space Telescope will require the assistance of grants and contributions.

The Independent Space Research Group is the name adopted by the non-profit organization responsible for the development of the astronomical satellite. The ISRG is also committed to encouraging the use of space by amateur astronomers and others, and also to providing information and assistance to those who want to engage in scientific or educational space activities. The Group potentially has several other areas of interest, and the members feel that the ISRG can expand into other areas as time, money, and manpower permit. The ISRG has started publishing a newsletter to keep amateur astronomers and others interested in the project informed on developments. Subscriptions are $5.00 for six bi-monthly issues, and Supporting Memberships in the ISRG are also available for $10.00, which includes a subscription to the newsletter. For a subscription or more information, write to:

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Solis Lacus: A Martian Lake?

Radar information gathered by the 210-foot Goldstone radio telescope in California's Mojave Desert in 1971 and 1973 was only analyzed recently, and scientists have found the data indicate the presence of water on Mars.

Stanley Zisk, a radar specialist at the Massachusetts Institute of Technology's Haystack Observatory, and Peter Mouginis-Mark, a Brown University geologist, made the findings. Zisk said that the echoes bounced off a region of Mars known as Solis Lacus (Lake of the Sun) had the characteristics of a surface that is both highly reflective and smooth. Although he admitted the interpretations of the radar echo patterns are speculative, he added that they were not able to come up with alternative ideas to explain the reflectivity and smoothness.

He said that as the Goldstone antenna continued to bounce radar pulses off the planet in the late spring and summer of 1971 and 1973, the reflectivity seemed to grow greater. This would be a pattern one would expect to see if water were present.

Four years ago, the two Viking spacecraft placed in orbit around Mars found evidence that some liquid once flowed down the slopes of Mars, cutting channels and flowing across the low plains. Most likely this liquid was water.

If there is water in Solis Lacus, it would not exist as a surface body of water, but could be anywhere from 20 to 40 inches below the reddish-brown surface in the form of damp soil or pools of subsurface water, Zisk said.

Solis Lacus, in the southern hemisphere, is approximately 600 by 300 miles in size. Had these findings been made before 1976, the discovery might have influenced the choice of the site for the second Viking lander.

Asteroid Jimarnold

A chemistry professor at the University of California in San Diego (UCSD) has found himself one of the few living persons to have an asteroid named after him. Asteroid 2143 Jimarnold was named by its discoverers, Eleanor Helin and Eugene M. Shoemaker, planetologists at Caltech, for Professor James Arnold of UCSD.

Originally designated 1973 SA, Jimarnold was discovered on September 25 (Sept. 26 UT), 1973. On discovery it was located in the constellation Pisces. Observation on subsequent nights led to a preliminary determination of the new asteroid's orbit, which showed it to be an unusual Mars-crossing asteroid.

Helin and Shoemaker have been studying asteroids whose orbits bring them near Earth — the so-called "Earth-grazers" — and even closer to the Sun. Those asteroids with relatively small orbits are called the "Apollo" asteroids, from the Greek god of the Sun. In the process Helin and Shoemaker have discovered a number of other asteroids, including 2143.

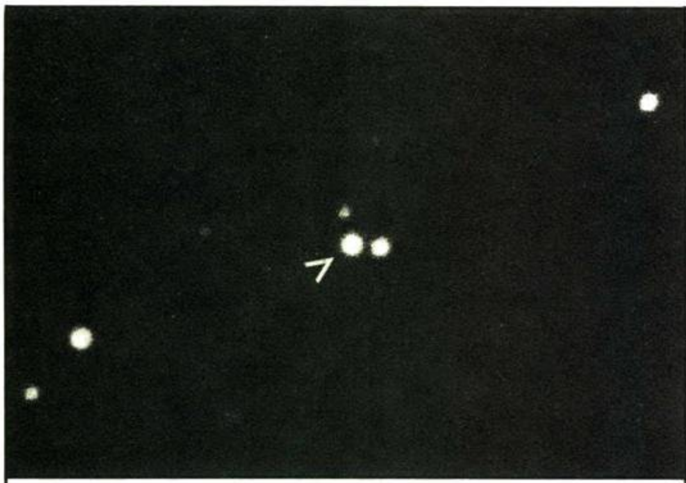
At first, Helin and Shoemaker anticipated that others would observe 1973 SA, and since their original program was to detect Earth-crossing asteroids, they did not attempt further observations from Palomar. But 1973 SA was not observed again, and the researchers realized it was in danger of being "lost," since a definite orbit had not been calculated. Other plates were located which showed 1973 SA, but it wasn't until Charles Kowal of Caltech made additional observations in December 1977, that they could be sure it wouldn't be lost.

During still later apparitions in 1978-79, the Agassiz Station of the Harvard College Observatory made observations of 1973 SA which qualified it for numbering and finally, naming. On the basis of its brightness, 2143 Jimarnold is estimated to be about eight miles long.

Arnold, for whom asteroid 2143 was named, is director of the newly created California Space Institute. He made substantial contributions during the 1960s to the study of asteroids. More recently he has made extensive studies of the geochemistry of the lunar rocks brought back by the Apollo astronauts.

"I've had quite a number of small scientific honors, but I've never had as much fun over any honor as I have over this one," Arnold said. At a party to honor Arnold and asteroid 2143, the scientist donned a "2143 Jimarnold" T-shirt and announced that he was ready to talk to any real estate agents. He pointed out that, according to the present understanding of the geology of asteroids, Jimarnold should have a high gold and platinum content.

Asteroid 2143 Jimarnold on October 1-2, 1973. Photo courtesy of Eleanor Helin.



Quasar 3C 147: Your physics textbook is correct even there! Hale Observatories photograph.·

Physics Works Everywhere

An essential assumption of all astrophysics and cosmology is that the physical laws observed to be valid here on Earth are equally valid throughout the universe. Without such an assumption, astrophysics would be virtually impossible, since there would be no way of knowing how physical laws varied from point to point in time and space.

Although this assumption is a reasonable one to make, it has been notably lacking in proof. Observations of the spectral characteristics of other stars in our own Galaxy and others in the nearby galaxies (such as M-31) comprising the Local Group have long been construed as proof that at least the same physical laws apply to our immediate cosmic neighborhood. But it was only last year that observational evidence was gathered for the first time extending the range of confirmation of physical laws to more distant galaxies (see "The Physics of Distant Stars," AstroNews, May 1980). Even so, the most distant galaxy studied at that time was M-101, 24 million light-years away.

Now two scientists at the University of Pittsburgh have found evidence to extend the claim of uniformity of physical laws to a cosmic scale. Writing in the March 15, 1980 issue of the *Astrophysical Journal*, Allan D. Tubbs and A.M. Wolfe report the results of their study of observations of four distant quasars. Their work, Tubbs told ASTRONOMY, "presents the first strong evidence that the laws of physics throughout the *entire* universe are virtually indistinguishable from those determined in terrestrial laboratories. While this was often assumed in the past," Tubbs continued, "it has never been *proven* before."

The method Tubbs and Wolfe employed was to study the characteristics of the absorption spectra of four quasars at different wavelengths. From this they deduced that three very important fundamental physical constants were uniform across the distances and times involved. This confirmation of the large-scale uniformity of physical laws, they point out, depends only on the assumptions that the large redshifts observed in quasar spectra are indeed due to their recessional velocity at a great distance, and that the cosmic background radiation is indeed, as it seems to be, isotropic (uniform over the entire celestial sphere).

A (Slightly) Variable Sun

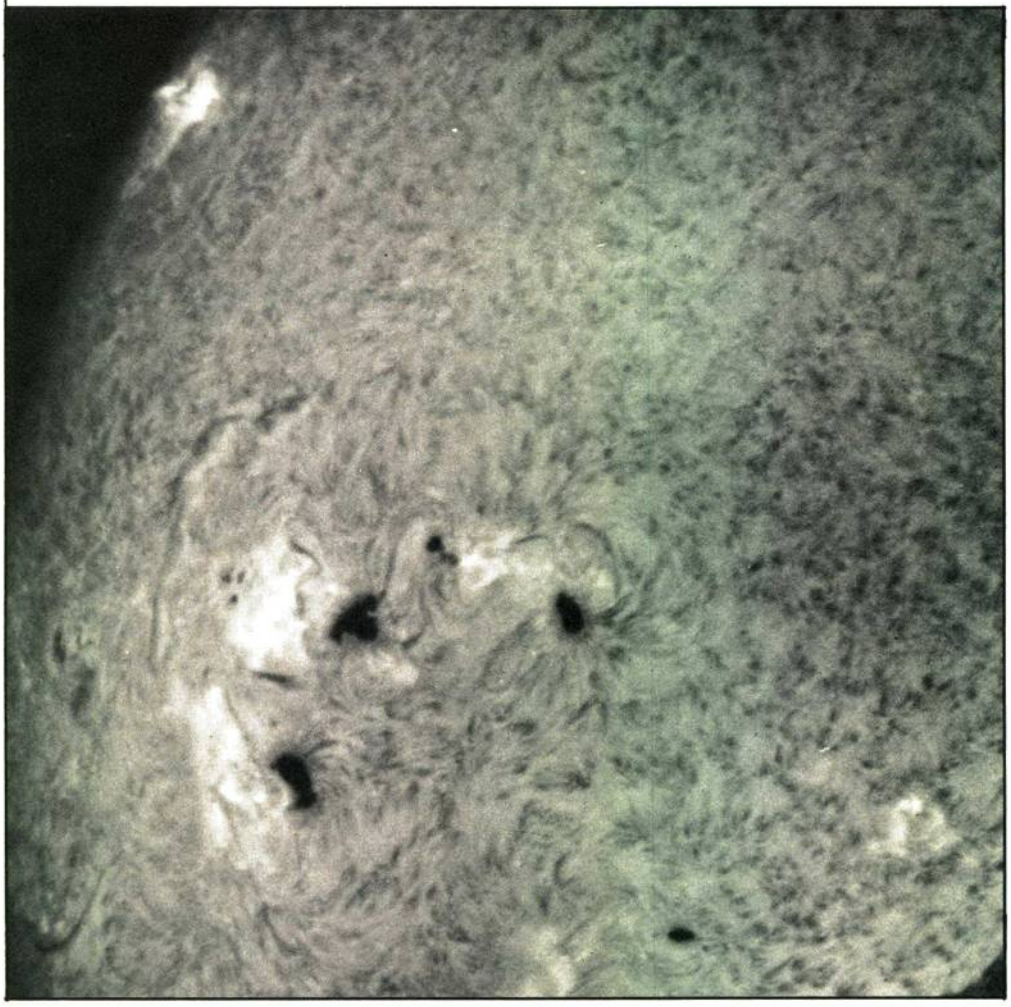
Detection of even the slightest change in the amount of light and heat energy emitted by the Sun is important because if a trend were to continue for several years, it could produce major alterations in the Earth's climate. Measurement of such trends might enable scientists to predict future climate changes.

Now, using a new type of measuring device flown in space for the first time, NASA scientists have detected small changes — over periods of days to months — in the total radiation emitted by the Sun.

Fluctuations of about one-tenth of one percent have been seen several times by an experiment aboard the Solar Maximum Mission satellite. These fluctuations in solar radiation correspond to a change of up to 10 degrees Celsius (18 degrees Fahrenheit) in the Sun's average surface temperature of about 5700° C (10,300° F).

The newly-measured changes in the Sun's output of

The active Sun of June 1980 is seen in this H-alpha filtergram taken by Edwin Hirsch. The Sun's total radiation output has been found to be slightly variable.



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energy may be related to sunspot or solar flare activity, according to meteorologist and physicist Dr. Richard C. Willson of the Jet Propulsion Laboratory in Pasadena, California, who developed the instrument to measure the Sun's radiance for the Earth-orbiting satellite.

The instrument, called an Active Cavity Radiometer Irradiance Monitor and one of seven experiments on the satellite, is capable of detecting changes in the Sun's release of energy as small as one thousandth of one percent. The instrument measures a very broad range (X-rays to radio waves) of the radiation that falls on Earth's upper atmosphere. This represents well over 99.9% of the total solar radiation reaching Earth.

Theoretically, any increase or decrease in the Sun's release of energy — as little as 0.5% per century — can produce profound changes in Earth's climate. It is estimated that a drop of only 1% in solar radiation would decrease Earth's mean global temperature by more than 1° C (2° F). The entire Earth would be covered with ice if the Sun's radiation decreased by only 6%.

The entire history of humankind, lived out in the last several million years, has occurred during abnormally cold times. There is evidence that the Earth had been growing colder for about 90 million years, and scientists believe the average global temperature may drop 10 or more degrees in the next several million years.

150 million years ago, Earth was approximately 8° C (15° F) warmer than it is today. Since then, numerous warming and cooling climatic cycles have occurred. These cycles, which occur with frequencies ranging from 22 years to millions of years, have caused ice ages, ranging in severity from major glacial epochs to "little ice ages" lasting only a few hundred years.

The last "little ice age," which began in the mid-17th century and lasted through the mid-19th century, was marked by a 1½ degree drop from the present mean global temperature of about 14° C (58° F). This slight change in the Earth's average temperature resulted in an observable increase of glaciation in the Alps.

Amateur Directory

A guide to national amateur astronomy organizations is now available free of charge from the Astronomical Society of the Pacific. According to a survey just published in the Society's popular-level journal *Mercury*, approximately 15,000 individuals are members of nationally organized groups whose main aim is to promote and enjoy astronomy as a hobby.

Several of these groups have local chapters which hold star parties, conduct workshops about telescope building or observing, and meet regularly to hear lectures and share information about astronomy. Other groups make contact with their members by mail and hold annual conventions in various parts of the U.S. A few organizations sponsor active programs of amateur research, such as observing variable stars and other objects which professional astronomers do not have time to monitor on a regular basis.

As part of its work to inform the public about astronomy, the Astronomical Society of the Pacific (an international, non-profit educational organization) is making copies of its survey and directory available to interested individuals. Addresses, main activities, and publications are listed for each group.

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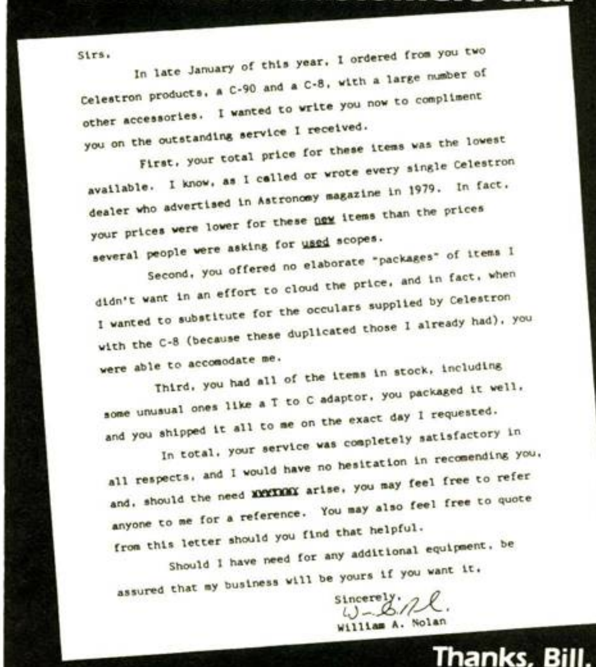

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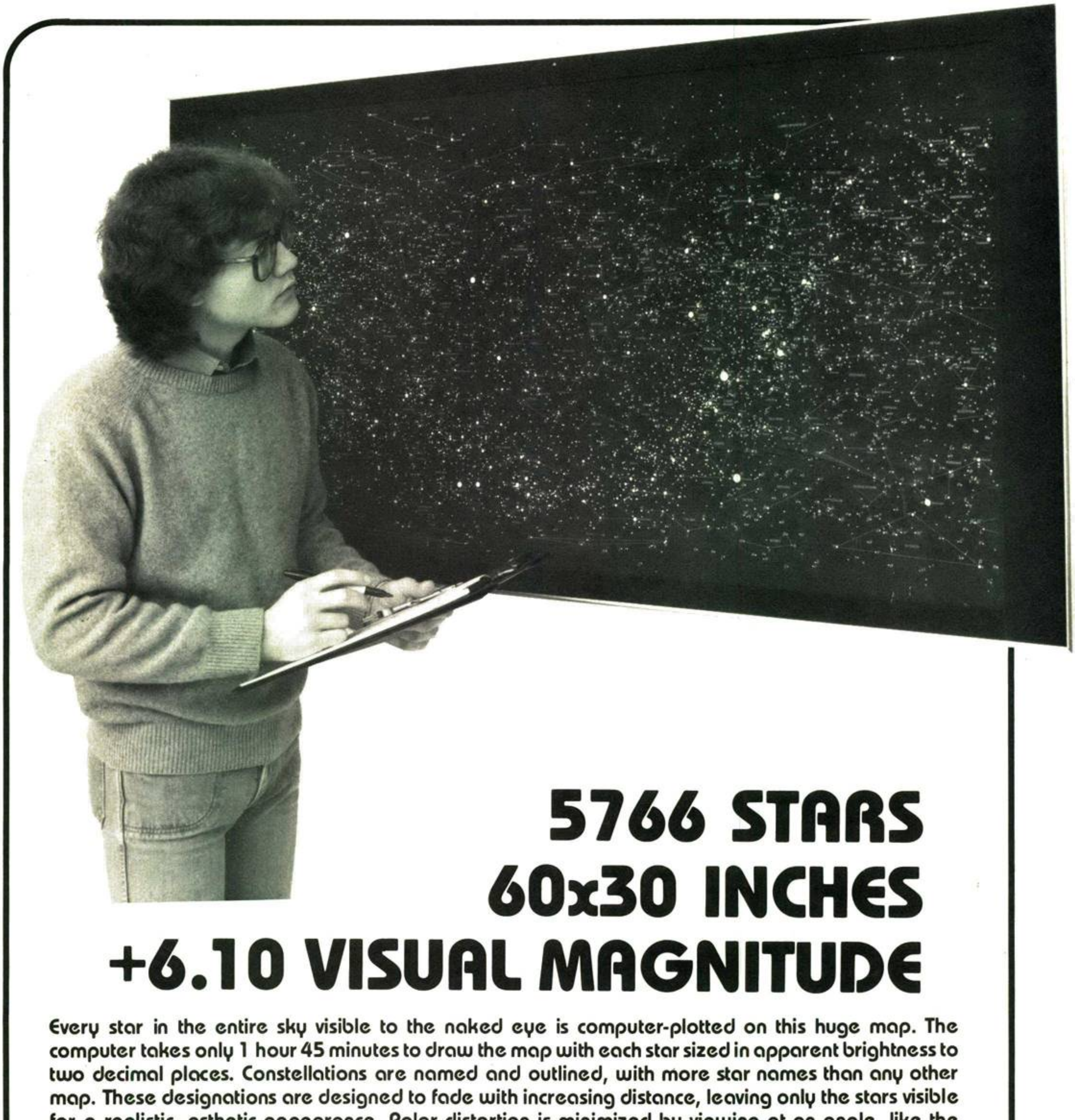

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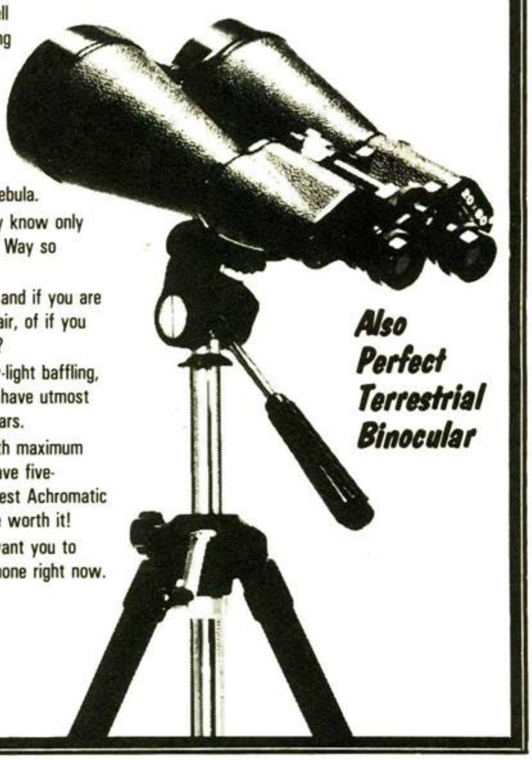

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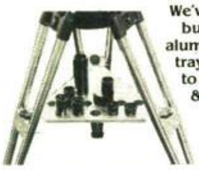

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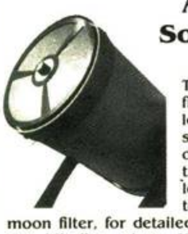

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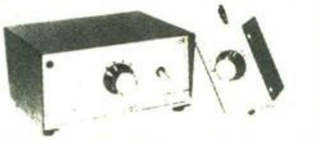

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Space, Time, and Black Holes

by David Darling

Few concepts have challenged the intellect and imagination of man like that of the black hole. From the mathematical stratosphere of applied General Relativity to the celluloid fantasy-world of Hollywood, this most exotic of cosmic inhabitants has become the basis for far-reaching (and often wild) speculation.

Where lies the true interface between the fact and fiction of black holes? If they exist, and the evidence is compelling, how would they appear from the outside? And how from within?

If black holes appear to rank with quasars, quarks, and gravity waves among the esoteric revelations of modern science, this isn't really the case. Three years before the dawn of the 19th century, the French theorist Pierre Laplace discussed the possible existence of bodies so massive that even light could not escape from their gravitational pull. Yet the idea was generally ignored or forgotten — forgotten, that is, until its resurrection in a new and more compelling form with the advent of Einstein's General Theory of Relativity in 1916.

The black hole emerging from the relativistic field equations is infinitely more complex, bizarre, and intriguing than that envisaged by LaPlace. Over 60 years of brilliant investigative work following the first announcement of Einstein's new theory of gravity have taken us to the very core of the black hole and beyond. And if the history of black holes has been spectacular so far, what of their future?

Expedition to a Black Hole?

An era at the periphery of our imagination: it is the 30th century, and man has conquered the stars. Starships sail the interstellar seas, like their terrestrial ancestors on missions of trade and exploration. The trip to Alpha Centauri and back has become the rich Earthling's retirement cruise. "New Sol" colonies in the planetary systems of Epsilon Eridani, Epsilon Indi, and 61 Cygni have achieved independence from Earth and now offer stellar stepping stones for man's deeper penetration of the Galaxy. And now the ultimate journey is about to commence.

The first robot probe to the infant luminous supergiant HDE 226868 and its invisible companion confirmed what astronomers for ten centuries had suspected. The initial pictures from the probe showing swirling tongues of star matter stretching from the young supergiant to a spectacular cosmic whirlpool nearby were the first signs of the beast. Then the concluding evidence quickly followed as the high-resolution cameras scanned the star-shredding companion to reveal a magnificent, gleaming accretion disk and its inevitable black-eyed center. "Project Columbus Proves Cygnus X-1 Is a Black Hole!" read an ASTRONOMY article in July 2932.

Now, 50 years later, a second artificial satellite tracks a slow orbit around HDE 226868. The pull of the black hole proved to be more than just gravitational. Man had seen the creature from the outside, had been drawn to it as if to some cosmic siren, and was now poised on the edge of eternity — about to plunge in!

Let's return to the present with perhaps an image from the future in our minds. A starship, built with a technology we can only dream of, hovers in space a few million miles from the jaws of a ten solar mass black hole. Using resources and techniques a thousand years more advanced than our own, the ship's designers have, we trust, found methods to counteract the immense tidal forces exerted on anything approaching and entering a black hole.

Our scenario is set. As the starship *Jules Verne* leaves the relative safety of an orbit around the tormented supergiant and heads for its climactic rendezvous, let's ourselves venture into the strange world of the black hole.

Relativity and Black Holes

It's easy to fall into the trap of judging the laws of physics by our everyday experience. Surely it goes without saying that "basic" quantities like mass, length, and time don't depend on the observer's state of motion. When was the last time you saw an aircraft grow in length as it taxied to a halt on the runway? How often have you discovered that your watch has been running slow while you were driving to work? Observation confirms again and again that such bizarre events simply don't occur. As Isaac Newton concluded over 300 years ago, mass, length, and time ought to be absolute properties of the universe — constants unrelated to the observer's frame of reference.

Likewise, it's "obvious," our senses firmly convince us, that the space in which we live is "flat." The Earth, the solar system, the galaxy, the universe itself — all are set in a perfect Euclidean, three-dimensional space, simple and predictable. Or so it seems...

And gravity? Ah yes, a strange thing, that gravity. Anything which has mass will try to draw you toward it with a pull that varies directly as the mass and inversely as the square of the separation distance. This relentless tug, this "gravitational attraction," isn't something you can see or easily perceive a mechanism for. And, somewhat mysteriously, gravity stretches its far-reaching tendrils across the voids of space, binding planets to their life-giving suns, bending the paths of stars in their endless galactic flights, and securing the allegiance of whole galaxies to their designated cluster or supercluster.

For a quarter of a millennium, the science of physics grew and flourished from the seeds sown by Newton. His theory of gravity, his concepts of the absolute nature of space and time, stood like the pillars of some ancient coliseum — strong and timeless. Then, incredibly, and within the space of a few years, they were swept away to be replaced by a new, more subtle view of the universe. First in 1905, with his Special Theory of Relativity, then again in 1916, with his General Theory, Albert Einstein changed the way we view the nature of space and time.

The changes were dramatic. Classical physics, and the Newtonian universe as well, were shown to be reasonable approximations for normal terrestrial conditions and environments, but hopelessly myopic in the extreme conditions of, say, high speed or intense gravitational fields.

We don't need to explore all the intriguing avenues of relativity theory here, or venture into the abstract realm of the math underlying them. But to perceive the nature of black holes a little more clearly, it'll be useful to do some model-building. The very unusual, slightly disturbing conclusions of Einstein, become more accessible when framed in familiar terms and ideas.

Newton had no model for gravity. To him, there was nothing to be added to the fact of its existence, *its inevitable* association with a massive body, and the experimentally verifiable inverse square law of its behavior. No "reason" for gravity. Until Einstein.

Imagine this: an immense flat sheet of rubber stretching in all directions as far as the eye can see. We roll a heavy metal ball out onto the sheet. And where it comes to rest we see that it creates around itself a depression, a slight warping of the rubber. We roll out another ball, this time a lighter one made of plastic. The path of this second object remains perfectly straight until it gets within close range of the depression made by the first, where it bends perceptibly. On re-emerging from the curved region of the rubber sheet, the lighter ball's path has changed and now continues as a straight line in a new direction.

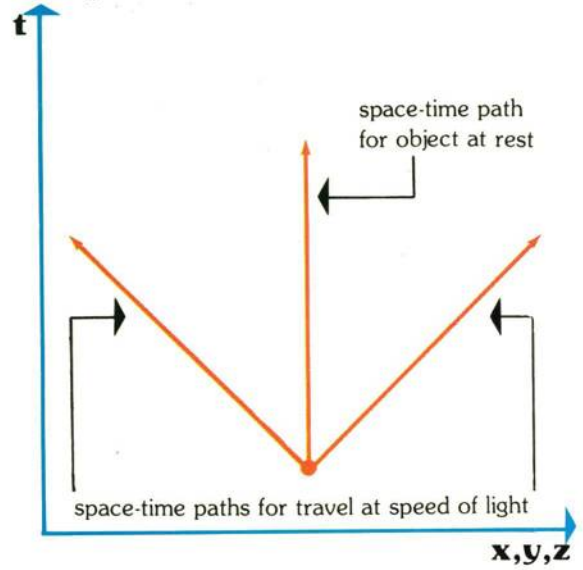
A simple experiment, offering very little in the way of surprises — at least to us. The bending of the second object's path was obviously caused by the local curvature of the rubber sheet. It appears clear to us who can see the true shape of the sheet, that anything which is confined to moving along the sheet's surface will be affected by this local warping. And, in turn, it's apparent that the warping itself is a result of the presence of massive objects. Even the light plastic sphere traced a shallow dip in the sheet as it moved.

Now, switch perspectives. Imagine that you're a two-dimensional being, an inhabitant of the same rubber sheet we talked of above. In this new world, "breadth" and "width" are still familiar concepts, but the terms "height" or "thickness" are inconceivable; they have no meaning. The rubber sheet has become the "space" in which you live, and, because a third dimension is now inaccessible, it's impossible for you to look down on this space and spot where it may be "flat" or "curved." The best you can do is study the motion of objects in your two-dimensional world, and draw conclusions from your observations.

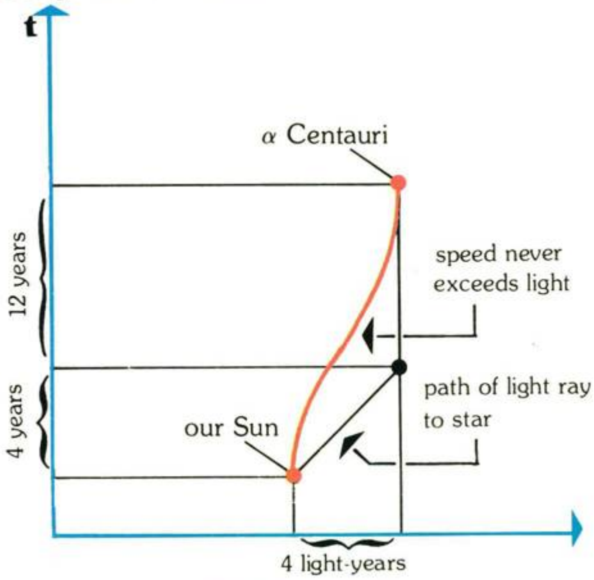
One thing stands out like a beacon. Wherever there is something that has the property called "mass," there emanates from it a force which tends to attract all other objects in the neighborhood. There's no obvious way of accounting for this ubiquitous force, this so-called gravity. Yet it clearly exists, and has certain well-defined properties.

Two-dimensional dwellers of the rubber sheet could

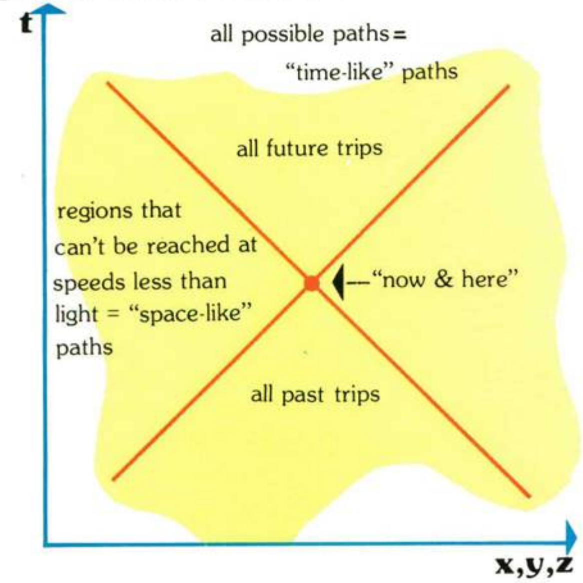
The Space-Time Axes


t
space-time path for object at rest
space-time paths for travel at speed of light
x,y,z

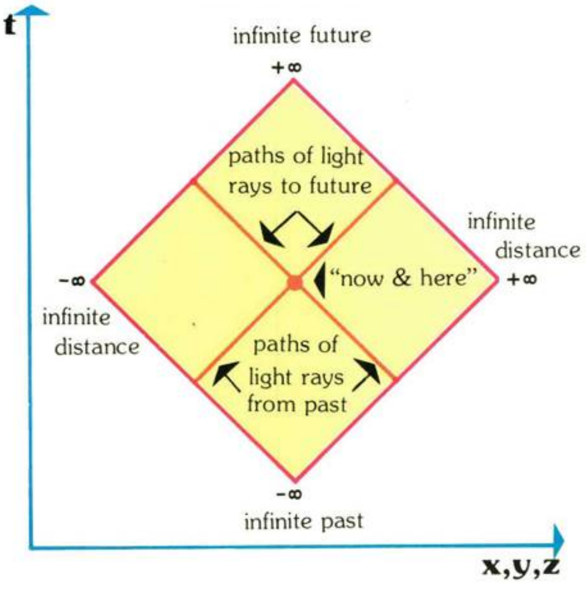
Trip to a Star


t
α Centauri
speed never exceeds light
path of light ray to star
our Sun
12 years
4 years
4 light-years

Space-Time Travel


t
all possible paths = "time-like" paths
all future trips
regions that can't be reached at speeds less than light = "space-like" paths
"now & here"
all past trips
x,y,z

"Collapsed" Map of the Whole Universe


t
infinite future
+∞
paths of light rays to future
infinite distance
+∞
-∞
infinite distance
"now & here"
paths of light rays from past
-∞
infinite past
x,y,z

be said to have a Newtonian viewpoint. Gravity to them is predictable but unexplainable. To discover that "gravitational forces" are really a direct outcome of the local curvature of space, we need to step out of the surface of that space and into a higher dimension. Then we get the bird's-eye view, the Einsteinian perspective: gravity as a manifestation of the curvature of space. To be accurate, we should use the term "curvature of space-time," in accordance with Einstein's key discovery of the intimate association between space and time.

In our own space, which our senses tell us is three-dimensionally flat, it still seems reasonable and obvious to adopt the Newtonian concept of gravity. But our senses are inadequate; they experience only a tiny, highly localized region of space, a region which is a good approximation to being flat. Einstein tells us to shift our viewpoint. Space is, in reality, curved. The presence of matter, whether it be on the galactic, stellar, planetary, or even atomic level, bends what would otherwise be a textbook three-dimensional Euclidean space through a fourth dimension.

Now, Einstein didn't have some unique ability to visualize things in four dimensions. The concept of curved space, or, more correctly, curved space-time, evolved quite naturally and necessarily from his General Theory of Relativity.

The Einsteinian revolution began in 1905 when Special Relativity burst onto the scientific scene. Based on just one observational fact — namely, that regardless of any relative motion between observer and source, the speed of light is constant — Einstein overturned previously held ideas on the nature of space and time.

Special Relativity arrives at some pretty breathtaking conclusions. And it's hardly surprising that they weren't reached earlier when you consider that speeds comparable to that of light have to be attained before things start to get interesting. Mass, length, and time behave in some very unexpected ways for observers moving at very high speeds relative to each other.

Like the Special Theory, General Relativity is based on just one observation. The "Equivalence Principle," as it's called, simply affirms that you can't distinguish between acceleration and the phenomenon we call gravity. It has far-reaching consequences, the most obvious of which is the complete demolition of the notion of a gravitational "force." Gravity for the first time is seen as a natural outcome of the "shape" of space-time around any massive object.

The more mass something has, the deeper is its "gravity well," or the hollow it causes in space-time. In addition, the more compact that object's mass — in other words, the higher its density — the steeper will be the sides of the gravity well.

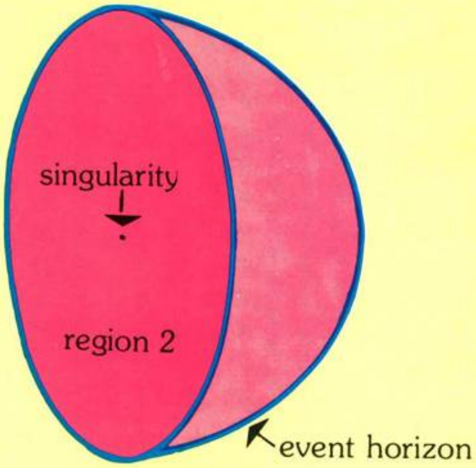
The most noticeable of the gravity wells in our region of space, besides those of the Earth and Moon, is that in which the Sun resides. Over 99% of the mass of the solar system fuels the solar furnaces, and the space-time depression which all this matter causes extends far beyond the orbit of lonely Pluto. Were the Earth to be stopped dead in its orbit, the slippery slopes of the Sun's gravity well would quickly claim a planet-sized addition for the solar energy reserves.

Now, as stars go, the Sun is a very moderate specimen. Indeed, its classification as a main sequence "yellow dwarf" tends to dispel any belief that we might revolve about a stellar celebrity. When the Sun's prime nuclear energy reserves become exhausted around 10 thousand million years hence, most of the remaining solar matter will collapse down to form a high density object called a "white dwarf." Astronomers have found many examples of these hot, carbon-rich stars. They are doomed stars, lacking the ability to rekindle any remaining nuclear fuel and hence avoid the slow relentless cooling process leading to oblivion and darkness.

During the stable years, the so-called "main sequence" period of a star's existence, the inward pressing force of gravity is held at bay by the ample radiation pressure generated by thermonuclear fusion in the core. Once that outward pressure is lost, however, gravity continues unresisted, at least for a while, in its attempt to squeeze the star out of existence. In the case of a Sun-like star, things only begin to stabilize again when those tiny subatomic particles, the electrons, start to get sufficiently close together. Effectively the electrons say: "That's far enough. If I go any closer to my neighboring electrons I'll have to violate a powerful law of particle physics" (the Pauli Exclusion Principle).

But for stars heavier than around 1.25 suns, the matter doesn't rest there. The mutual repulsion of the electrons isn't sufficient to counteract the crushing onslaught of gravity. The old and dying star finds itself unable to rest in peace as a modest white dwarf. Electrons are rammed into protons to form neutrons, and the entire mass of the star is squashed into an incredibly dense ball of pure nuclear fluid, no more than 10 miles across. Now it is the "degenerate pressure" of the tightly crammed neutrons instead of electrons which makes the last-ditch stand against gravity.

Schwarzschild (non-rotating) Black Hole



There is a third possible fate for a star once its nuclear reserves are spent. For stars with more than about three times the mass of the Sun there is no known force in the universe that can prevent a complete gravitational collapse. Once the residual neutron pressure has been breached, the ultimate state of collapse is inevitable. And the ultimate state is...

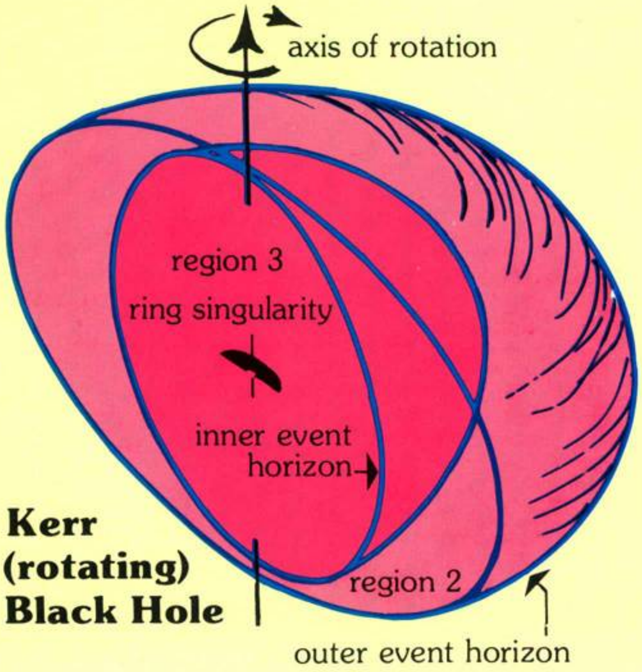
The black hole: an object whose gravity well has such sheer sides that even light is unable to climb out from it. But let the unsuspecting beware! From a distance, the space-time curvature around a black hole appears like that of an ordinary star — no different, in fact, from the star from which it formed. Close in, though, the situation is dramatically different. The seemingly innocuous star-like gravity well is in reality bottomless.

There's no restriction on the possible size of black holes, though we tend normally just to think of those which come about from the collapse of heavy stars. By "black hole" we mean simply any region where the curvature of space-time is great enough to prevent light from escaping.

Black holes, at least in principle, can come in all sizes, from colossal star-gobblers at the heart of "active" galaxies (see "The Quasar Connection," ASTRONOMY, December 1979) to pinhead-sized nomads possibly formed during the Big Bang.

Oddly enough, considering the spectacular and chaotic series of events which herald their formation, black holes are fairly simple objects. Their size is determined purely by their mass, and mass is one of just three properties that can be associated with a black hole. The other two are angular momentum (a measure of the amount of spin) and electric charge. Incredibly enough, from a knowledge of this triad of properties, we can specify a black hole's complete external and internal space-time structure.

Think of how many physical properties are associated with a normal star. Temperature, pressure, opacity, mass, chemical composition, magnetic field, speed of rotation — all of these things and more must be known for even a preliminary description of the stellar structure. How much simpler is the description if that star becomes a black hole! During the collapse through the "surface" of the black hole — the surface from which light cannot escape — all the complex information about the state of the dying star is forever lost. The situation is summed up well by the famous phrase of Princeton theorist John Wheeler: "Black holes have no hair!"



Kerr (rotating) Black Hole

Schwarzschild (non-rotating) Black Holes

Simplest of all black holes are those described by the German astronomer Karl Schwarzschild following his discovery of a solution of the relativistic field equations in 1916. The Schwarzschild solution deals with what we might call an "ideal" black hole — one whose sole attribute is its mass. It's difficult to see how such objects could come about in the real universe — we'd normally expect at least angular momentum as well as mass. But they offer us a very useful introduction to some basic concepts associated with black holes.

As we've seen, above the critical mass of around three solar masses, there's nothing which can prevent a star from sliding into the abyss of its self-made black hole. Let's then consider the black hole formed just a few seconds after, say, a 10 solar-mass supergiant buckles against the relentless crushing force of gravity. The star was exceptional, we'll assume, in that it wasn't rotating.

We need to bring in three astrophysical buzz words right away in order to describe out "ideal" black hole. Slightly less than 30 miles from the center of the black hole is the so-called "photon sphere," a region where light particles have been drawn into closed, circular orbits. Photons approaching on paths that take them closer than 30 miles to the black hole are sucked irrevocably into the heart of the object. Those passing beyond the photon sphere are merely deflected in their journey (remember our rubber sheet analogy). The photon sphere is a precarious region for a light particle to be in — any slight deviation of its path inward would condemn it to a one-way journey to oblivion.

Within the photon sphere, and perhaps 18 miles from the center, lies the true surface of the black hole. The "event horizon," as it's termed, is the spherical surface around a black hole from within which no information can ever pass to the outside world. It acts like a one-way valve from this universe to...

To where? What are things like inside the black hole, beyond the event horizon? And what's become of all the star debris that's the very cause of the immense space-time curvature?

The answer to the last question is that everything that falls through the event horizon of a non-rotating black hole automatically heads toward the center and the "singularity" which exists there. And what's a singularity? Answer: a single point in space where our equations predict there is infinite density, a dimensionless region where our current physical laws break down and become meaningless.

If a black hole forms from a non-rotating object — in other words, if it ends up with zero angular momentum — there's no way for something crossing the event horizon to avoid hitting the central singularity. Should we then cancel our mental voyage on the *Jules Verne* to avoid the unpleasantness of being squeezed at infinite pressure into a zero volume? We can be sure that whatever method by which the ship avoids being atomized by tidal forces on approach would be worthless under such extreme conditions.

Kerr (rotating) Black Holes

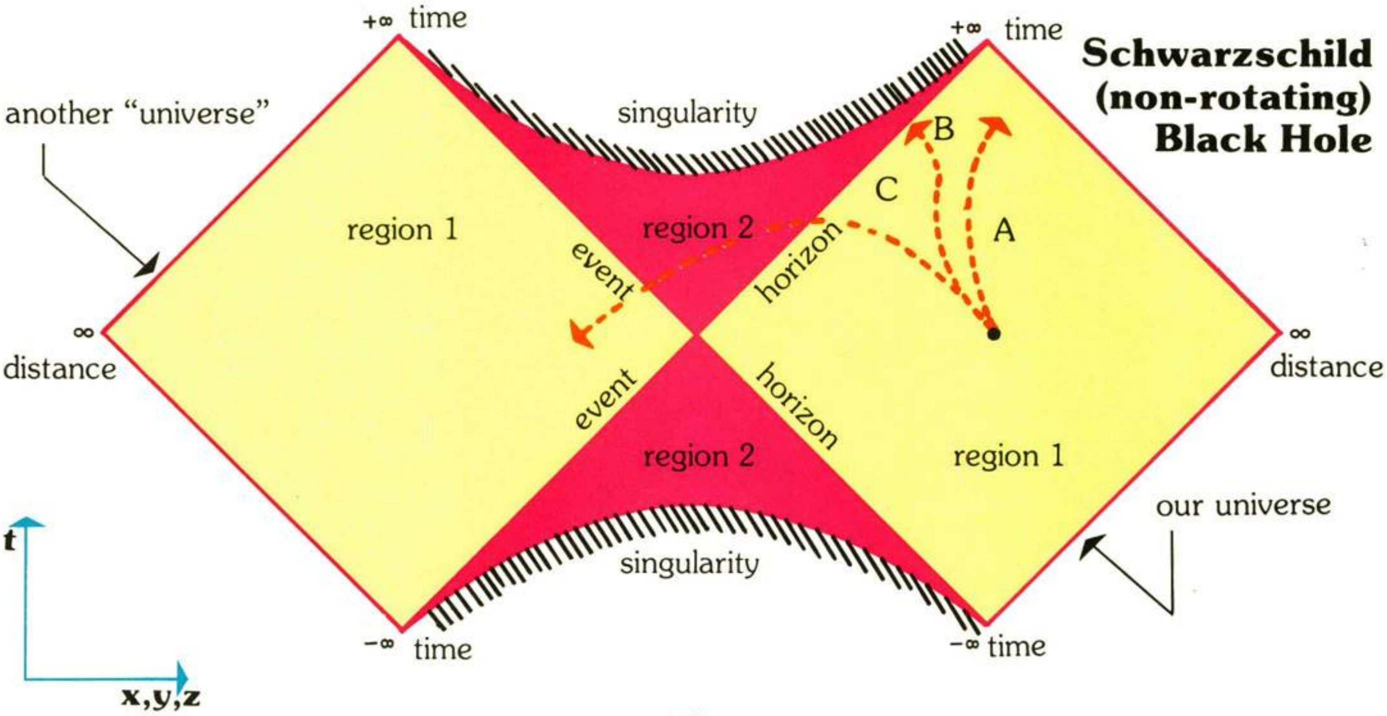
Yet we shouldn't be so hasty to cancel the journey. We've already mentioned that a black hole which only has mass would be rather exceptional and unrealistic. Stars, in reality, rotate about an axis, and any black holes resulting from them should do likewise. Angular momentum, like energy, is a conserved quantity, and a 10 solar mass supergiant with x units of angular momentum should collapse into a black hole also with x units (assuming no loss of mass).

Real black holes, then, almost certainly spin. And spin alters radically the internal structure of these objects. As the *Jules Verne* spirals closer and closer to the Cygnus X-1 event horizon, let's make a note of the key landmarks within a rotating black hole.

Discovered in 1963, the so-called Kerr Solution to Einstein's field equations reveals a much richer space-time structure for the case of a spinning black hole. First, in going from the static Schwarzschild black hole to the rotating Kerr object, the event horizon splits in two. Second, the nature of the singularity changes in a very significant way.

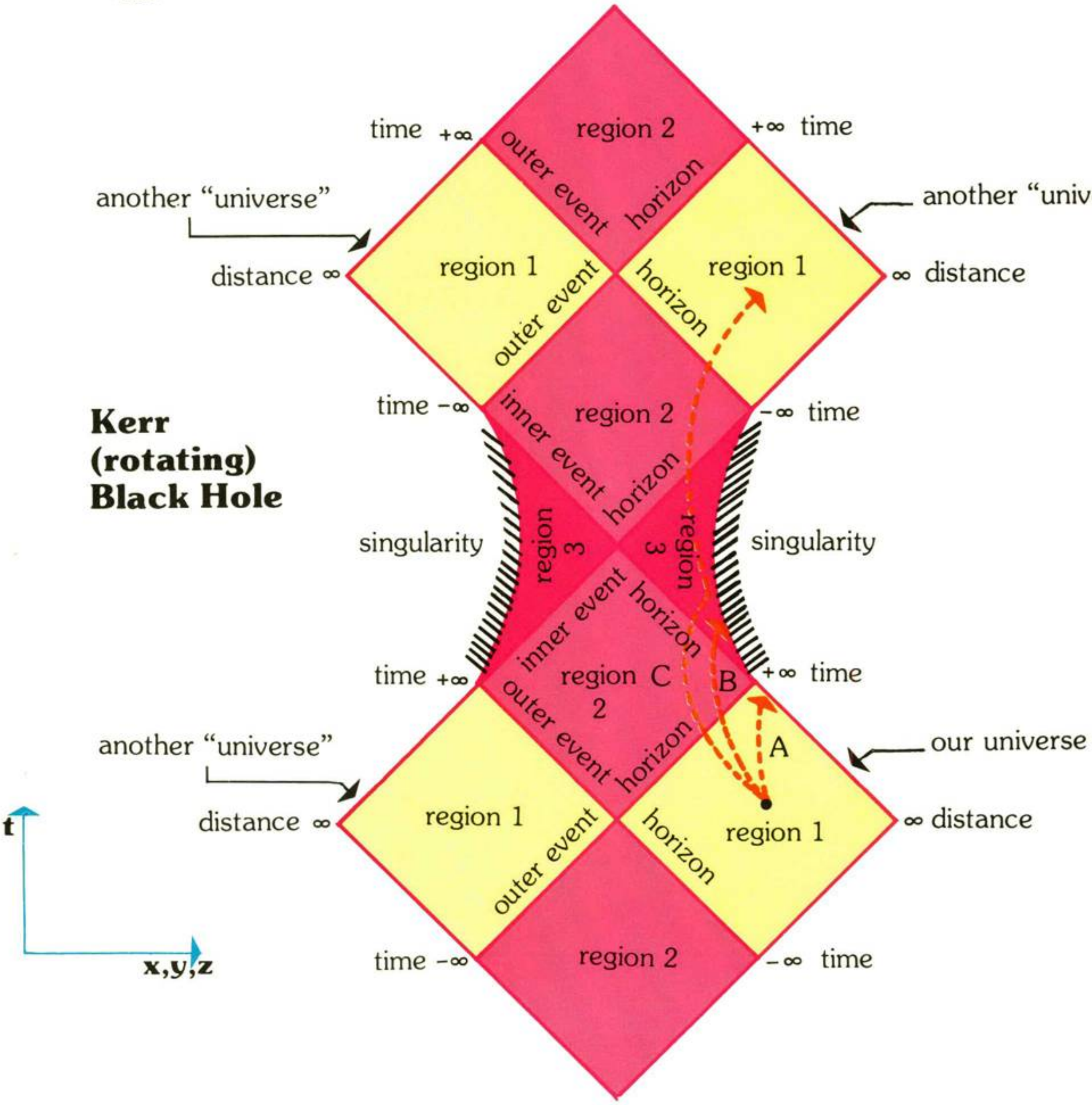
Event horizons splitting in two? A new type of singularity? The curious space-time makeup of a Kerr black hole threatens to stretch our imaginations to the breaking point. Maybe what we need more than anything else is some easy graphic way of representing space-time in and around a black hole.

Enter the ingenious Kruskal-Szekeres Diagram, a comprehensive map of the space-time inside a black hole. At first sight it looks distinctly odd, very different from the type of maps that we might be familiar with. But once we begin to understand the meaning behind the diagram, the



Schwarzschild (non-rotating) Black Hole

+∞ time
+∞ time
another "universe"
singularity
region 1
region 2
event
horizon
C
B
A
∞ distance
∞ distance
event
horizon
region 2
region 1
our universe
singularity
-∞ time
-∞ time
t
x,y,z



Kerr (rotating) Black Hole

region 2
time +∞
+∞ time
outer event
horizon
another "universe"
another "universe"
region 1
region 1
distance ∞
∞ distance
outer event
horizon
time -∞
-∞ time
region 2
inner event
horizon
singularity
singularity
region 3
region 3
inner event
horizon
time +∞
+∞ time
region 2
C
B
A
outer event
horizon
another "universe"
our universe
distance ∞
∞ distance
region 1
region 1
outer event
horizon
time -∞
-∞ time
region 2
t
x,y,z

way in which various components of space-time are represented, we can lay bare some of these deeper mysteries of black holes.

Take a close look at the Kruskal-Szekeres diagram for a non-rotating Scwarzschild black hole. Notice that time is represented by the vertical axis, and increases as we go from the bottom of the diagram to the top. Time flows up the page. All of the dimensions of space, on the other hand, are compounded into the single horizontal axis.

One of the most important conventions used in Kruskal-Szekeres Diagrams is that the paths of things traveling at the speed of light are represented by lines going at 45° to the space-time axes. Thus you'll find two such 45° lines dominating the space-time map of the black hole. Notice that they're both labeled "event horizon." And since the escape velocity at the event horizon is exactly equal to the speed of light, you'll see that this ties in very neatly with the Kruskal-Szekeres' space-time map. A photon at the event horizon, attempting to pull away from the black hole, would succeed only in holding a stationary position. The best that such a particle could hope for would be to follow the space-time path of the event horizon for the rest of time. A sublight-speed object, of course, would not fare so well.

No material object can cover as much distance — as much "space" — in a given amount of time as a light photon can. In the Kruskal-Szekeres Diagram, then, anything other than light must travel along paths that are inclined at more than 45° to the space axis. Such paths are called "time-like" in the vocabulary of the physicist. By contrast, a hypothetical object moving faster than the speed of light would follow a "space-like" path, inclined at angles of less than 45° to the horizontal.

We can draw an immediate conclusion from this — a pretty grim one as it turns out — for anything that crosses the event horizon of a stationary black hole. It's simply this: Whatever goes into such a black hole is trapped there forever. To escape would involve following a space-like path, and therefore breaking the relativistic speed limit of 186,281 miles per second.

Look closely at the dotted paths in the Schwarzschild black hole diagram. Path A involves simply a "close encounter" with the black hole, a relatively safe route which curves across Region 1 of the diagram (between our universe and the event horizon) and gives the event horizon a wide berth. Notice that at all points, Path A is time-like.

Path B is also time-like, but any traveler who takes this course makes the fatal mistake of crossing the event horizon. Once within the event horizon of a stationary black hole (Region 2) there are no time-like paths available which avoid the central singularity (curved shaded region). A super-light-speed particle could theoretically follow a space-like path, such as Path C, and so find its way into a second universe beyond the black hole, but such particles are of course impossible.

A non-rotating black hole, then, is a pretty desperate place to be, unless you happen to be fond of infinitely high pressures and densities. But what of a spinning black hole? Just how does the rotation affect the structure of space-time within the object? And what options does the new structure offer to the intrepid explorer who penetrates the event horizon of a spinning black hole?

Now look at the Kruskal-Szekeres Diagram for a Kerr (rotating) black hole. Don't be put off by its apparent complexity. We can quickly find our way around by spotting some of the principal landmarks.

The rotating black hole certainly suffers no shortage of event horizons. Two pairs of "outer" event horizons and one pair of "inner" event horizons are apparent here. In the central part of the diagram, the part which includes the singularities, the Regions labeled 3, and the immediately adjacent Regions labeled 2, there is a very interesting feature. Notice, in particular, that this central part is very similar to that in the diagram for a non-rotating black hole, except that it's turned through 90°. The result is that instead of creating an impenetrable block to anything crossing the event horizon, the singularities of a Kerr solution form the walls of a space-time "tube" leading from one side of the black hole to the other.

Through a Black Hole

The fearless crew of the starship *Jules Verne* wish to journey to the center of the black hole, and then on, hopefully, to emerge intact on the other side. But what path should they choose?

Path A is time-like, and hence possible, but merely skips around at the periphery of our universe without crossing the outer event horizon.

Path B is suicidal. It terminates at the singularity — strikes the wall of the space-time tube, if you like — after crossing both outer and inner event horizons.

Path C, or one similar, is the only reasonable choice. The *Jules Verne* begins by traversing Region 1 between our universe and the outer event horizon. Once within the black hole, having crossed the outer event horizon, the ship is compelled to journey through Region 2 (the region separating the inner and outer event horizons) and reach the inner event horizon. Penetration into Region 3 heralds the start of the most hazardous phase of the mission. It is during the trek across Region 3 that collision with the singularity is possible. *But not inevitable.* Remember the nature of the singularity is significantly different in a black hole that's spinning.

The starship holds a steady time-like trajectory which intersects with the opposite boundary of the inner event horizon a few moments later. Danger from collision with the singularity has now passed. Having emerged on the "other" side — the future side — of Region 3, only impossible, space-like paths could take the ship back to the singularity. The captain of the *Jules Verne* orders a final course change; the ship crosses the outer event horizon and emerges into another universe on the far side of the black hole!

We have reached almost the end of our mental voyage through space and time. We have seen how rotating black holes in our universe may be the doors of corridors in space-time leading to other universes. Matter and energy, even if not in so highly organized a form as men and spaceships, can follow allowable, time-like paths through those corridors linking the universes.

The diagram is, in reality, a simplification of the space-time structure of a Kerr black hole. A more accurate Kruskal-Szekeres Diagram would reveal the structure shown as just one segment of a pattern that repeats over and over again linking a great many universes. Depending upon the interpretation, the final pattern could stretch out forever in an infinite number of universes. Or the pattern might wrap around — a kind of cylindrical arrangement — so that journeys to other spaces and times within our own universe become possible.

The opposite end of a black hole is called, logically enough, a "white hole." And what plunges into a black hole in our universe may eventually gush out from a spectacular white hole in another. Even today, through the eyes and ears of our far-seeing telescopes, we may be witnessing the outpourings from white holes of matter that came from other universes or from different spaces and times of our own. Could this be the secret of the enigmatic quasars? Watch this space....

David Darling received his doctorate in astronomy from the University of Manchester (England). His last ASTRONOMY article was "The Quasar Connection," December 1979.

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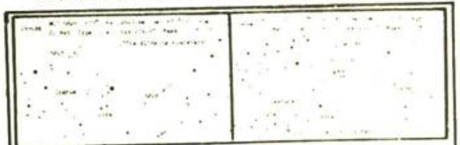

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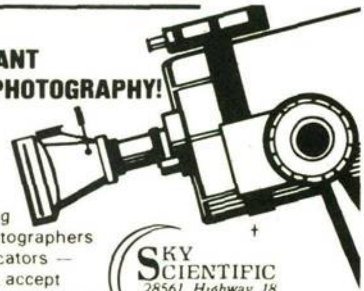

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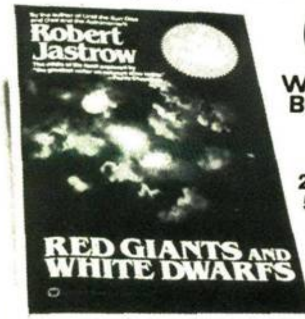

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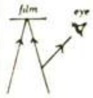

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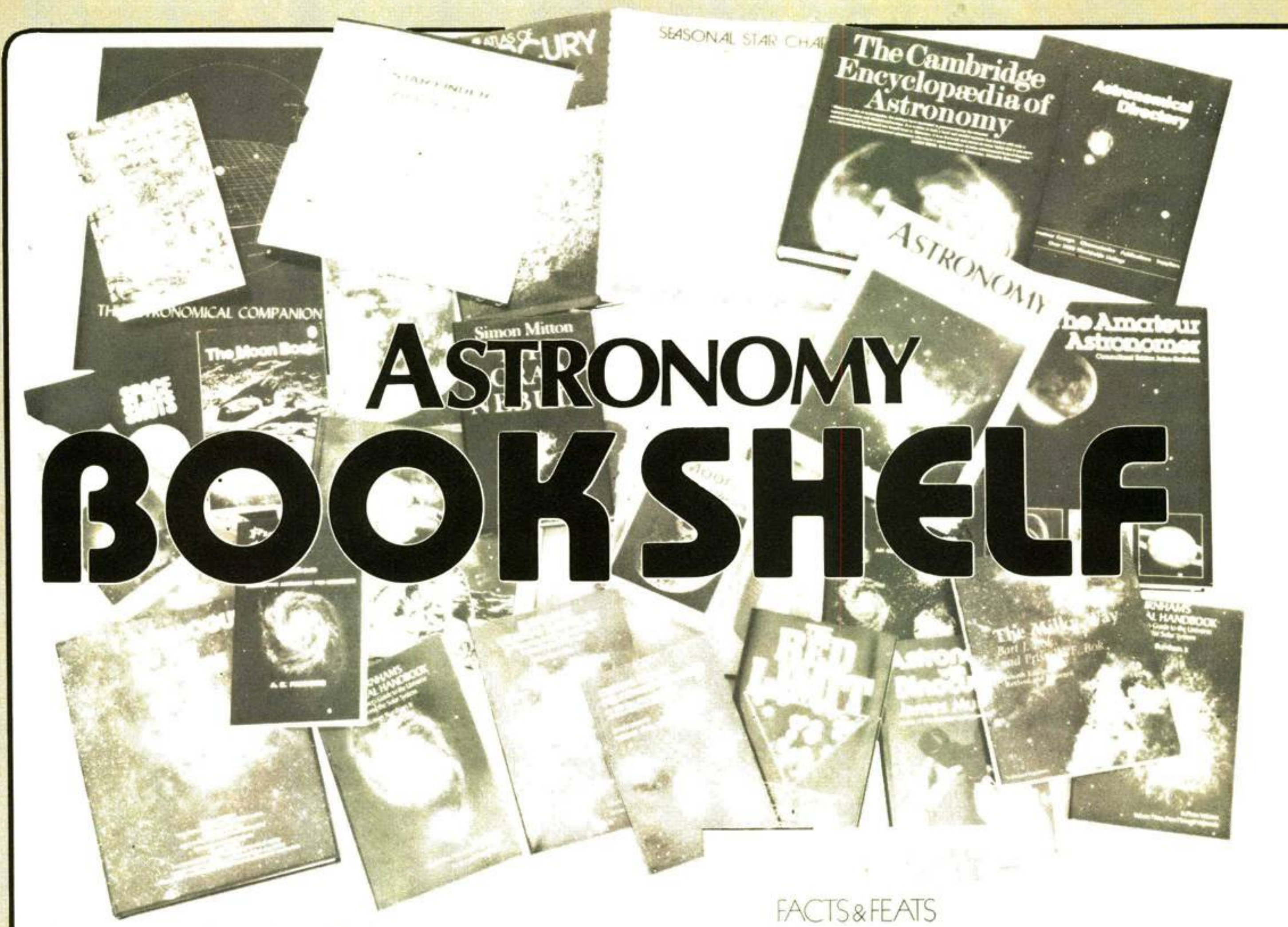

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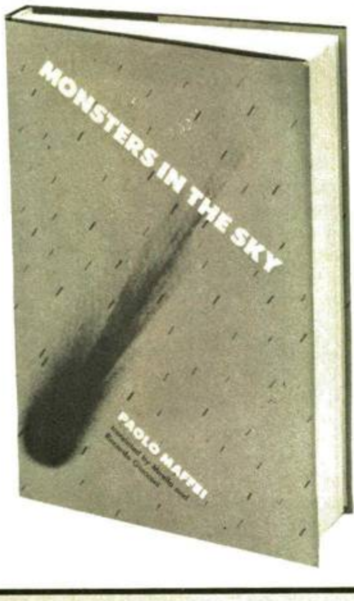

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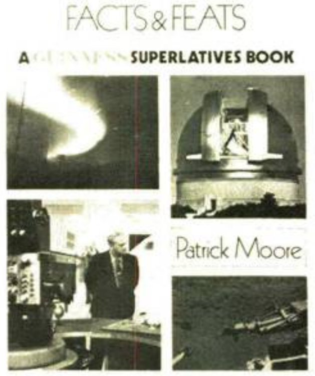

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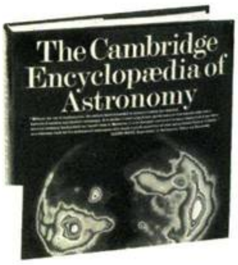
Celestial Objects for Common Telescopes, Webb Volume 1 is about the solar system; volume 2 covers all else, constellation by constellation. Paper, $9.00 (set).

Star Names: their lore and meaning, Allen The classic source for learning about star names, zodiac, constellations, and celestial folklore. Paper, $6.50.



Cambridge Encyclopaedia of Astronomy, Mitton Up-to-date survey of modern astronomy; fully indexed for easy access and thoroughly illustrated. Hardcover, $36.50.

Constellations, Rukl Popular pocket-sized guide to the constellations. Has color map on one page with a list of objects facing it. Hardcover, $4.50.

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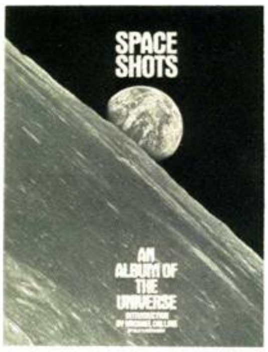

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Astronomical Directory, Gall Lists addresses and phone numbers for astronomical societies, planetariums, and amateur astronomers all over the world. Paper, $7.25.

Astronomical Calendar 1980, Ottewell Takes you through the year, day by day, explaining all such astronomical events as occur. Paper, $8.50.

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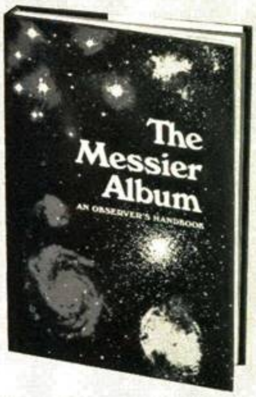

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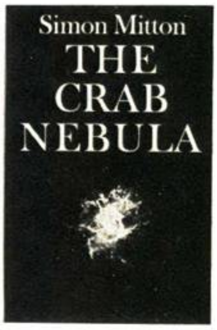

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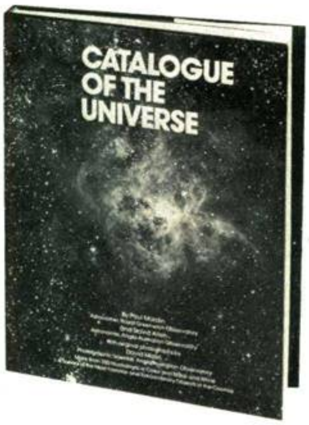

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close-up on pisces

through the eyepiece

October inaugurates an interesting and photogenic spate of conjunctions — Moon and planet, planet and planet, planet and star — that'll continue for several months, most taking place in the dawn hours. Even if you have to rouse yourself exceptionally early, don't miss out — there are some exciting sights in store.

Mercury

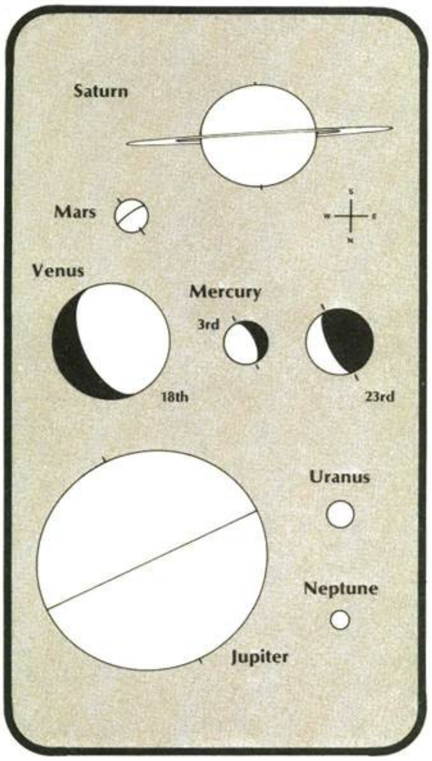
As if in counterpoint to the above, Mercury's evening elongation this month isn't much to get excited over. Even at its highest, you still won't see a lot: 1° elevation in azimuth 244°, 45 minutes after sundown on the 13th. Greatest elongation (eastern) comes two days earlier, on the 11th at 4^h UT with an angular separation of 25°. But because Mercury's declination this month lies in the range of -15° to -20°, observers in the northern hemisphere can't see it very well at all.

Which is a shame since the elongation is an *aphelic* one, meaning that Mercury lies at or near its farthest orbital distance from the Sun. If we could view from farther south on Earth, the time for observation between sunset and Mercury-set would last substantially longer. For example, 45 minutes after sunset in Buenos Aires on October 13th, you'd see Mercury 14° high in the west-southwest. Compare that with our 1°!

Venus

On October 4th and 5th, Venus will be very close to Regulus, Alpha (α) Leonis, in the eastern sky. Passing 16 minutes of arc south of Regulus, Venus will lie to the right of it on the morning of the 4th and below it on the 5th. (Conjunction in right ascension comes at 15:40 UT on the 4th.)

The Moon, a slim crescent 24½ days old, will be about 10° to the upper right of the pair on the 4th. Early on the 5th, it'll pass Regulus (at 5:05 UT) and Venus (at 6:29 UT). Since the conjunction with Venus comes before the objects rise, even for the extreme eastern parts of North America, onlookers will have to be content with the later view of the Moon below and beside the brilliant (-3.6 magnitude) planet.



Truly enthusiastic observers may want to observe the actual conjunction of Venus with Regulus. At the time mentioned above (15:40 UT), Venus will be about 50° to 60° high depending on where you live, so if the sky's crystal clear, you've hope of seeing it. Locate Venus by offsetting from the Sun (be CAREFUL!!) $2^h 36^m$ of right ascension to the west and 16° 26′ to the south.

At the end of October (on the 30th), Venus will meet Jupiter in the southeastern sky. As morning twilight begins to glow noticeably, the pair will be some 25° high in azimuth 112° and about a degree apart. The time of conjunction in right ascension is 20:24 UT on the 30th, the angular separation 27 minutes of arc, but as seen from North America, the Sun will be higher in the sky than Venus and Jupiter. Observers from the Rockies west are better off. At conjunction, Venus lies $2^h 17^m$ west of the Sun, and 15°14′ south of it; if skies are clear (high altitude also helps), try offsetting from the Sun.

In some telescopes, Venus now looks almost completely "full," though this is something of an optical effect. In reality, its phase is 70% illuminated, but a mediocre objective will convert its blazing light (-3.6 magnitude) into a rounder-looking image.

Moon

Apart from the fine conjunction with Venus and Regulus mentioned above (which appears as an occultation in some places outside North America), the Moon will join Jupiter very low in the eastern sky on the morning of the 7th. Forty-five minutes before sunrise, Jupiter will lie a degree or two to the right of a very slender crescent moon, 28 days old and only 4% illuminated. Both will be at an altitude of about 7° to 8°.

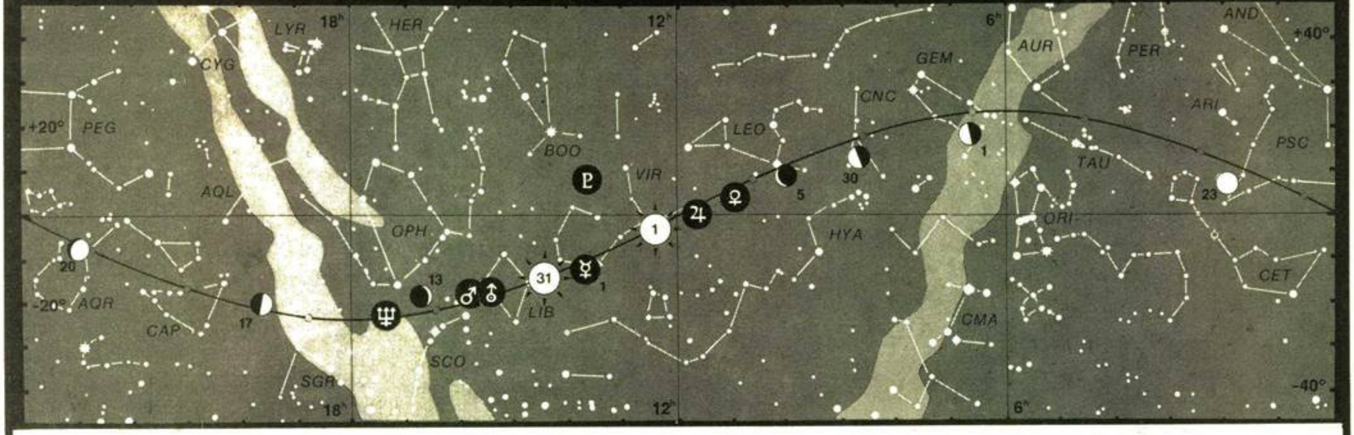
Mars

On the first of October, Mars is about 10° high in the west-southwest (azimuth 235°). It'll lose only about a degree over the course of the month and will hold about the same azimuth.

What's happening is that Mars' course along the ecliptic is beginning to "bottom out" as it heads for its

Taking first place in this month's "Best Astro-Photo" competition is Jack Newton's shot of M-27, the Dumbbell Nebula. A resident of Victoria, British Columbia, Newton loaded his home-built cold camera with Ektachrome 400 and ran the exposure for 18 minutes at the focus of his 16-inch f/5 telescope.

planetary data


18h
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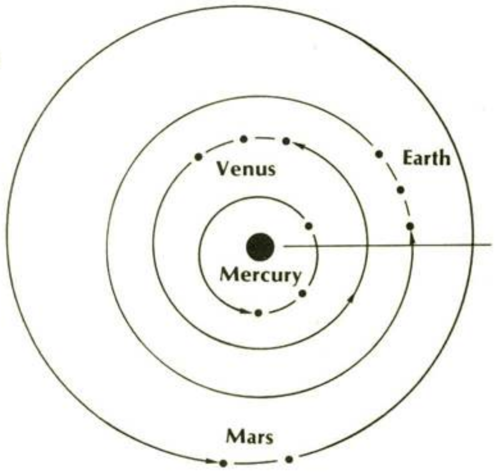
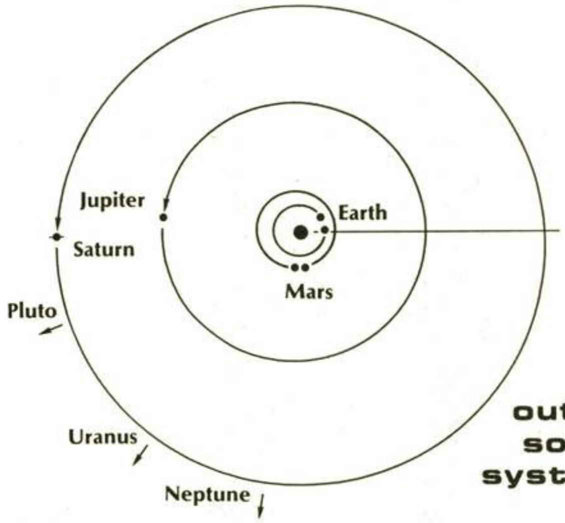
inner solar system


Venus
Earth
Mercury
Mars


Jupiter
Earth
Saturn
Mars
Pluto
Uranus
Neptune

outer solar system

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (1980.8)	Dec
Sun		10	--	32.1′	--	1.00	--	--	196°50.9′	13 02.1	-6°37.0′
		20	--	32.2′	--	1.00	--	--	206°45.8′	13 39.3	-10°18.9′
Mercury	☿	10	+0.2	6.5″	63%	1.02	0.44	296°27.8′	221°18.1′	14 34.0	-18°03.3′
		20	+0.5	7.9″	40%	0.84	0.39	331°04.1′	228°36.0′	15 03.9	-20°37.6′
		30	+2.2	9.7″	8%	0.69	0.34	16°33.6′	225°39.6′	14 53.7	-18°28.9′
Venus	♀	10	-3.6	16.0″	71%	1.05	0.72	90°12.9′	155°24.9′	10 31.3	9°53.5′
		30	-3.5	14.2″	77%	1.18	0.72	122°37.4′	179°03.6′	12 00.4	1°34.5′
Mars	♂	15	+1.5	4.5″	95%	2.07	1.46	268°14.3′	241°32.6′	15 58.7	-21°21.0′
Jupiter	♃	15	-1.2	31.2″	100%	6.33	5.43	173°10.5′	177°04.1′	11 52.5	1°58.8′
Saturn	♄	15	+1.2	16.0″	100%	10.44	9.51	180°57.3′	182°28.1′	12 28.1	0°46.1′
Uranus	⛢	15	6.1	3.5″	--	19.61	18.78	235°27.1′	233°26.6′	15 26.0	-18°30.1′
Neptune	♆	15	8.0	2.4″	--	30.78	30.28	262°02.6′	260°02.8′	17 18.7	-21°46.3′
Pluto	♇	15	14.0	--	--	31.06	30.10	201°42.5′	201°16.3′	13 44.9	6°56.7′

moon data

Last quarter	October 1 at 03:18
New moon	October 9 at 02:50
First quarter	October 17 at 03:47
Full moon	October 30 at 16:33

Apogee: October 9 at 15h	406,666 km
Perigee: October 23 at 14h....	356,759 km

universal time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times in Through the Eyepiece are UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5; MDT, 6; PDT, 7; Alaska and Hawaii, 9. For example, if an event is to happen at 03:00 hours UT on June 7, then the time in EDT would be 11 p.m. June 6. Likewise, 03:00 UT on Sept. 2 becomes, in PDT, 8 p.m. on Sept. 1.

NGC-253, the subject of Martin Germano's photo, is a spiral galaxy seen from only a little "above" its equatorial plane. As a result, its arms appear foreshortened and dark clouds of dust are silhouetted against the galaxy's stars. Forty minutes on 103a-F with an 8-inch f/10 got the shot.

southern declination limit. The background constellation on October 1st is Libra; at mid-month, it's Scorpius; by the 31st, it's Ophiuchus.

While in transit through the north-extending spur of Scorpius, Mars passes 3°44" north of Antares on the 24th. Conjunction in right ascension comes at 15:53 UT — when it's daylight over North America, so you'll have to wait until evening to look for the two together. At sundown +45 minutes, Mars will be about 9½° high, Antares 6½°, in azimuth 230°. It's a pity the conjunction isn't better timed, because comparing the brightness and color of these two objects, so linked in name (Ares = Mars in Greek), is good fun.

Earlier in the month, on the evening of the 2nd, Mars and Uranus are in conjunction. For details, see the section on Uranus below.

Asteroids

1 Ceres, at $7^h35^m06^s$, +23°35'27" (1950 coordinates) on the 15th, is a magnitude 7.6 dot in eastern Gemini and rises about local midnight.

2 Pallas lies near the Cetus-Eridanus-Fornax junction at $2^h30^m31^s$, -19°09'29" (1950) on the 15th. (At 4^h UT on the 20th, Pallas is at opposition.) The region clears the horizon mark by about 9 p.m. local daylight time and the asteroid has a visual magnitude of 7.9.

3 Juno, a month past conjunction, rises as twilight begins, only 85 minutes before the Sun. Give it another month to become well-visible.

4 Vesta is in Western Leo. Look for it at (1950) $9^h33^m48^s$,+16°23'16", where it's a magnitude 7.9 object. That part of the sky rises around 3:30 a.m. local daylight time.

7 Iris, a magnitude 8.5 asteroid, can be found at $23^h22^m43^s$, +6°56'48" (1950) on the 18th. This places it in western Pisces, where it sets about 6 a.m. local daylight time.

Jupiter

Jupiter reappeared in the morning sky late last month, and we'll now be seeing it climb steadily up and away from the horizon in the east. On the first, it'll be only 5° high as twilight brightens, but by the 31st, this'll increase to about 25°.

The planet isn't really prominent enough this month for good observations, and this is why there won't be a diagram for the jovian moons until next month.

On the 11th, Jupiter will pass less than half a degree north of Beta (β) Virginis, a star of 3.6 magnitude, but as they'll be only 12° high, a little south of east, the view won't be outstanding.

Saturn

Saturn, being about half an hour of right ascension to the east of Jupiter, is even more difficult to spot. It'll appear very low in the east on or about the 10th and by the end of October will be relatively close to Jupiter.

Uranus

Uranus' big event this month, such as it is, comes on October 2nd when Mars passes it by, a degree to the south. This will be one of those peering-low-into-the-twilight sort of things: 45 minutes after sunset, Mars is 10° high, Uranus 11°, in azimuth 234°. Mars' magnitude is +1.5, Uranus' 6. Best of luck!

Over the days following, Uranus sinks swiftly into the western twilight (conjunction with the Sun is on November 17th) and won't be seen again until late December when it reappears in the morning skies.

Neptune

Neptune likewise won't be around much longer in the west. As October begins, it's 23° high (az = 209°); by month's end, the elevation is just 15°

The early morning Sun rising over the Moon's highland region near Clavius (top center) and Tycho (bottom center) throws into bold relief a landscape pocked and battered by millions of meteoritic impacts. Brian Tkachyk made the 2-second exposure at f/90 with his 8-inch f/10 telescope on Kodak IV-E film.

(az = 224°). The difficulties in observing the dim (8.0 magnitude) and diminutive (2.4″ of arc diameter) planet are steadily growing.

Pluto

The 9th planet (can't call it "the Sun's most distant" anymore until 1999) moves into conjunction with the Sun on the 14th of October at 22^{h}UT, becoming a morning object.

Meteors

October offers two showers: the Draconids, which peak on the afternoon of the 9th, and the Orionids, peaking on the evening of the 20th.

The Draconids are relatively poor in numbers and usually produce a meager display. The radiant point lies near the head of Draco, which sinks lower and lower as the night wears on. Having peak activity before it gets dark will cut into the number of meteors seen, but at least the Moon is new and won't interfere.

The Orionids promise better. Their radiant lies near Orion's upraised club (northeast of Betelgeuse), a region which climbs steadily higher as the hours pass. The zenithal hourly rate is about 25; expect to see perhaps half that many during an average hour. The Moon will be three days past first quarter, but will have set by the time the radiant climbs highest (5:30 a.m. local daylight time).

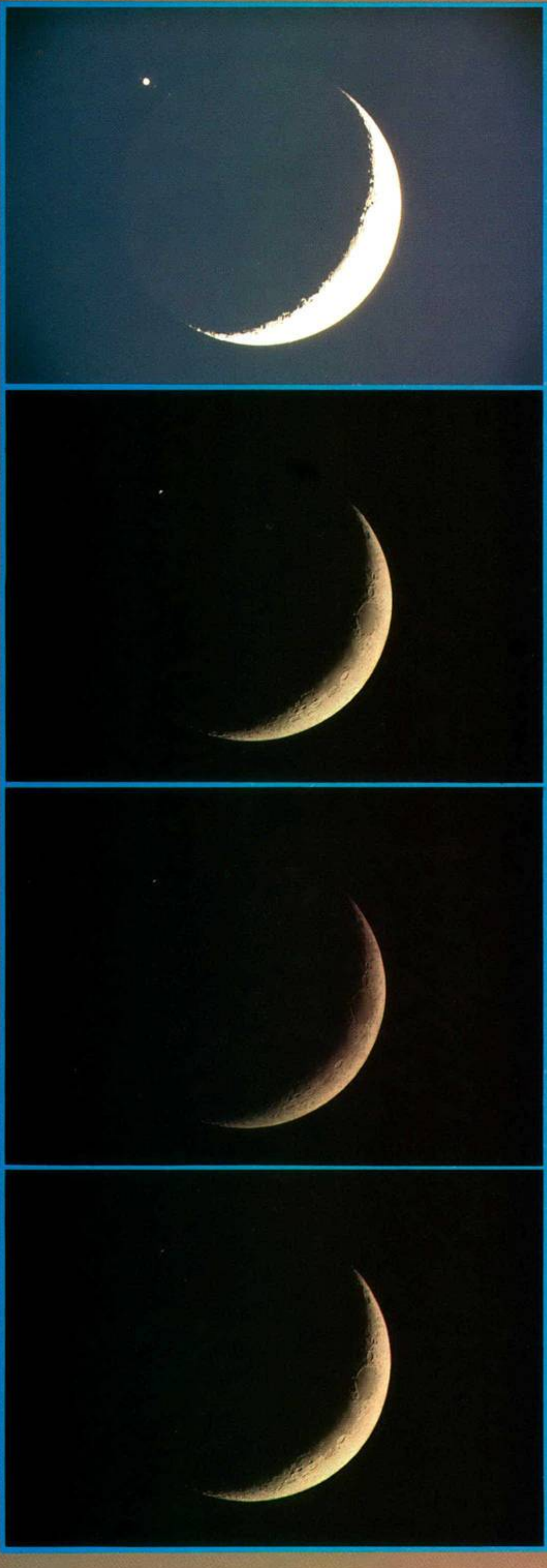
close-up on pisces

Well-known as a zodiacal constellation, Pisces is less than prominent in observational terms. The classic observer T.W. Webb called Pisces "a dull region, containing some good telescopic objects," and with good cause. The constellation has no stars brighter than the fourth magnitude, and its only prominent naked-eye feature is the circlet of stars just south of the Great Square of Pegasus formed by Iota (ι), Theta (θ), 7, Gamma (γ), Kappa (κ), Lambda (λ), and TX. But it does contain a number of pleasing doubles, as well as M-74 — one of the most difficult (and least observed) Messier objects.

Though bereft of clusters and nebulae, Pisces is sprinkled with a flock of dim galaxies, of which the brightest is the (still rather faint) spiral **M-74**. This neglected entry in the Messier catalog appears as a roughly circular glow some 11 by 9 minutes in size with a total integrated visual magnitude of 10.2. Much too faint for finderscopes, it is still relatively easy to locate since it lies just 1½° east and slightly north of Eta (η), the brightest star in Pisces. At magnitude 3.7,though, Eta is none too prominent itself, but a line from Alpha through Beta Arietis points directly at Eta, providing a quick zeroing in on the region containing M-74.

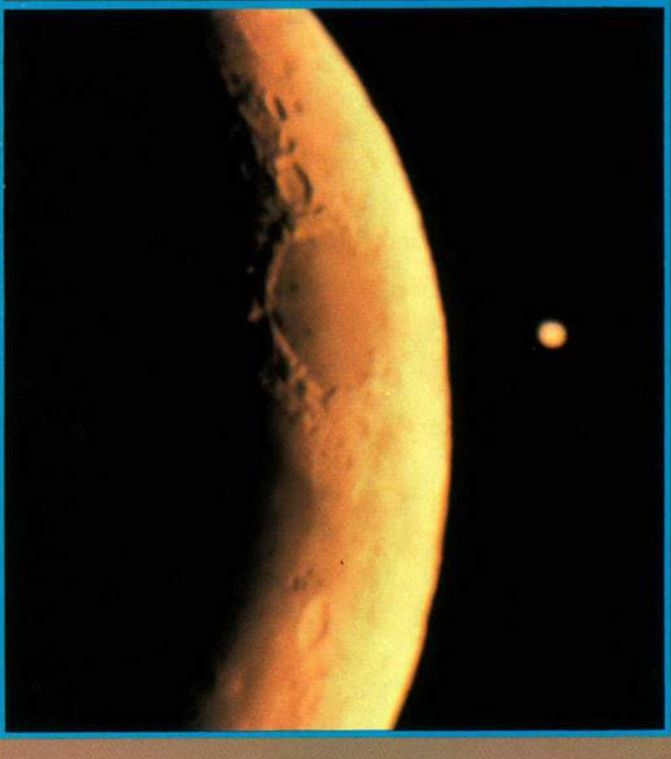
Once found, M-74 will reveal no structure except through apertures of eight inches or larger, although it is in fact a nearly face-on spiral. As this object is usually one of the last Messier entries to be bagged by those hunting down the entire list, you might do well to go after this one first while it is well-placed for observing on October evenings. Nab M-74, and the rest should be easy!

Two variable stars of interest are located within the confines of this inconspicuous constellation. The first on our list, **TX Piscium**, is famed for its deep reddish-orange hue. Actually a variable star with a small range of about one magnitude or less, TX is easy to locate as it is the easternmost of the stars forming the circlet of Pisces. No



The Occultation of Jupiter

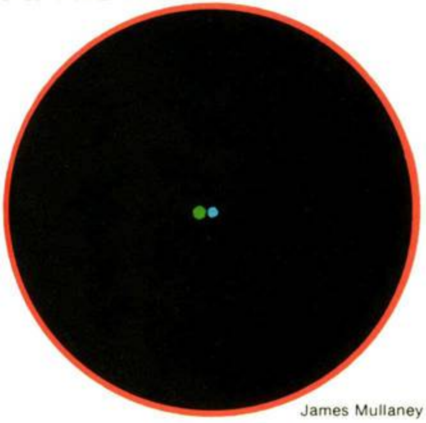
Left: A photo-sequence by Rev. Ronald Royer (Lakewood, California) shows, top to bottom, the progressive disappearance of the jovian system. Above: A general view by Rick Schmidt (Topeka, Kansas). Below: Jupiter after reemergence by Steve Reed (Corona, California).



M-74

Jack Newton

Al Rischa



James Mullaney

Roger Silva shot the Black-Eye Galaxy, M-64, with a 20-minute exposure on 103a-O with his 12½-inch f/5 telescope.

definite period has been found for the fluctuation in its brightness, so TX is classified as an irregular variable. Pickering included only five red stars over the entire sky in his famous list of showpieces, and TX is one of them — why not take a look yourself the next clear night, and enjoy the color of what Webb called a "magnificent object."

The other variable star on our list is the somewhat fainter **Z Piscium**, like TX a type N0 star, but with a less pronounced color because of its lesser brightness. Z is classified as a semi-regular variable with an observed period of about 144 days.

Now let's look at the double stars, the real strength of Pisces, beginning with the brightest (and closest) pair, **Alpha** (α) **Piscium**. Also known as **Al Rischa** (the only star in Pisces with a proper name), Alpha is in fact a quadruple system, since each of the two visible components has been revealed by spectroscopy to be itself a binary. Separated by only 1.8 seconds of arc (at position angle 290°), the two main components differ by less than a magnitude in brightness and are both A2-type stars.

It is the colors of these two close stars which have occasioned the most comment. Most viewers see the primary as greenish and the companion as bluish, though both stars may look white to you on first inspection. What Barns referred to as "weird coloring" is explained by a survey of past estimates. Flammarion included Alpha in his list of the 25 best doubles and described it as "blanches" (white). It appears as a runner-up in Pickering's roster under the heading "White Doubles." Olcott, however, recorded Alpha as green and blue, and Norton, pale green and blue. Bernhard, Bennett, and Rice noted "color contrast remarkable" and suggested shades of green-white and blue or even brown. Muirden said "curious tints, somewhat greenish." How do you find the colors of this remarkable stellar duo?

Zeta (ζ) **Piscium**, called by Burnham "a fine easy double star," was famed in sixth century Hindu astronomy because at that time the precession of the equinoxes brought it to within 10′ of right ascension of the vernal equinox. Separated by a comfortable 24 seconds of arc in position angle 63°, the two components differ in brightness by less than a magnitude. A delicate color contrast has been marked by many observers, the most poetic observation (quoted by Webb) being "yellowish and pale lilac or rose." Others, however, see no contrast, noting both stars as "pale yellow." The primary is spectral type A5 and the secondary F6, which suggests a subdued color contrast. How do you find them?

Two somewhat similar doubles in Pisces which are interesting to compare are 35 and 55, both composed of sixth magnitude primaries accompanied by dimmer secondaries. **35 Piscium** offers two stars of nearly identical spectral type — A9 and F0 — so there is no color contrast. Separated by nearly 12 minutes of arc at position angle 149°, the two components differ in brightness by close to two magnitudes. **55 Piscium** is a closer pair at 6.6′ separation (position angle 193°), with a greater spread in magnitude — from 5.6 for the primary to 8.8 for the secondary. Unlike 35, 55 offers a definite color contrast, for the primary is an orangish-red K0-type star while the dimmer secondary is a yellowish F3.

In his classic work *Star Names*, R.H. Allen notes that a minor nineteenth-century British astronomer named Maxwell Hall regarded the double star **65 Piscium** for some obscure reason as the "Central Sun of the Universe." Instead, 65 is a remarkably well-matched pair of nearly identical sixth-magnitude stars separated by 4.4″ in position angle 297° — definitely pleasing to behold, but hardly worthy of Hall's exalted title! Perhaps one of our readers can tell us what lies behind Hall's opinion of 65 Piscium's supposed cosmic pre-eminence.

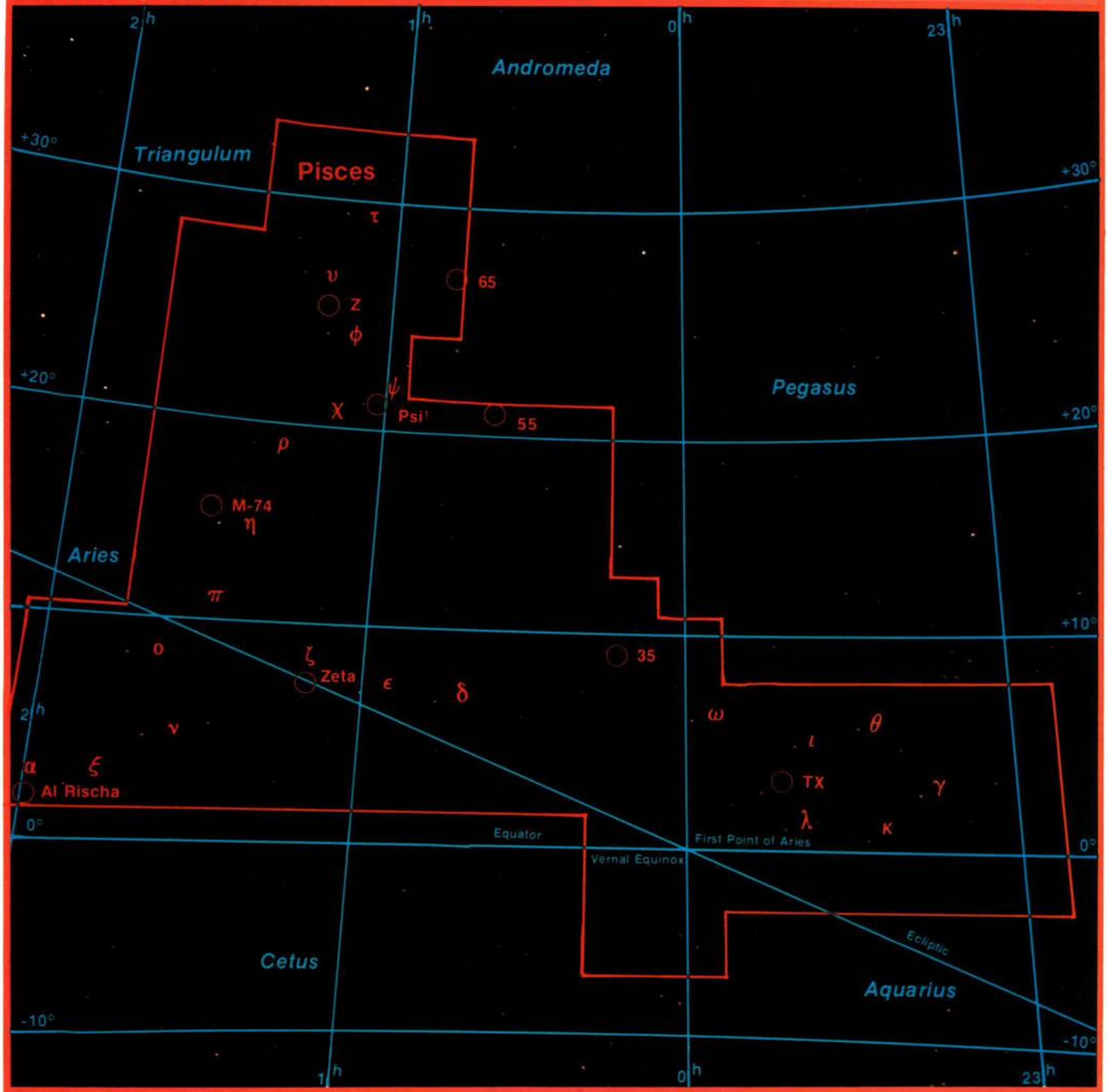
Like 65, **Psi^1** (ψ^1) **Piscium** is a nearly identical pair of stars. Somewhat brighter than 65, the two B9-type stars are separated by a healthy 30 seconds of arc in position angle 160°. Burnham lists a third component, Psi^1 C, an eleventh magnitude star 93 seconds distant at position angle 123°, and notes that the separation between components A and C is slowly declining.

Finally, let us look at the potential of Pisces for binocular sweeping, noted by many observers. For example, Chi (χ) Piscium is remarkable for the striking proximity of three stars in a line (Psi^1, Psi^2, and Psi^3 Piscium) in what Barns called an "amazing sequence." Other binocular sights are the apparent doubles formed by Rho (ρ) and 94 Piscium (dubbed a "splendid pair" by Webb), and Kappa (κ) and 9 Piscium (sometimes referred to as Kappa^1 and Kappa^2). Olcott noted that "the region about Kappa is particularly beautiful." And returning to Barns, we are advised that "superb sweeping" is to be found about Delta (δ), with 60 and 62 Piscium in the field, and that the grouping of stars 35, 36, 38, and 41 Piscium is a "region of splendors." When you go out to observe this month's objects, why not take along a pair of binoculars and check out the views that so impressed these classic observers?

Map by Dewey Schwartzenburg

pisces

Photo by R. Provin & B. Wallis



2h
1h
0h
23h
Andromeda
+30°
Triangulum
Pisces
+30°
τ
υ
65
Z
φ
+20°
ψ
Pegasus
χ
Psi¹
55
+20°
ρ
M-74
η
Aries
π
+10°
ο
35
ζ
Zeta
ε
δ
2h
ν
ω
θ
ι
α
ξ
TX
γ
Al Rischa
λ
κ
0°
Equator
First Point of Aries
0°
Vernal Equinox
Ecliptic
Cetus
Aquarius
-10°
-10°
1h
0h
23h

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (1980)	Dec.
TX	∩★	5-6	--	23^h44^m	+03°13′	23^h45^m	+03°23′
35	★^{2}	5.9,7.6	12″	00 12	+08°33′	00 14	+08°43′
55	★^{2}	5.6,8.8	6.6″	00 37	+21°10′	00 39	+21°20′
65	★^{2}	6.3,6.3	4.4″	00 47	+27°26′	00 49	+27°36′
Psi^1 (ψ^1)	★^{2}	5.6,5.8	30″	01 03	+21°12′	01 05	+21°22′
Zeta (ζ)	★^{2}	5.6,6.5	24″	01 11	+07°19′	01 13	+07°28′
Z	m★	7.0-7.9	144^d	01 13	+25°30′	01 15	+25°39′
M-74	§S	10	11′x9′	01 34	+15°32′	01 36	+15°41′
Alpha (α)	★^{2}	4.3,5.2	1.8″	01 59	+02°31′	02 01	+02°40′

★	*Star*
★^{2}	*Double Star*
★^{3}	*Triple Star*
m★	*Regular Variable*
∩★	*Irregular Variable*
Ӿ★	*Eclipsing Variable*
○	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
§0	*Elliptical Galaxy*
§S	*Spiral Galaxy*
§ʃ	*Barred Spiral Galaxy*
§#	*Peculiar/Irregular Galaxy*

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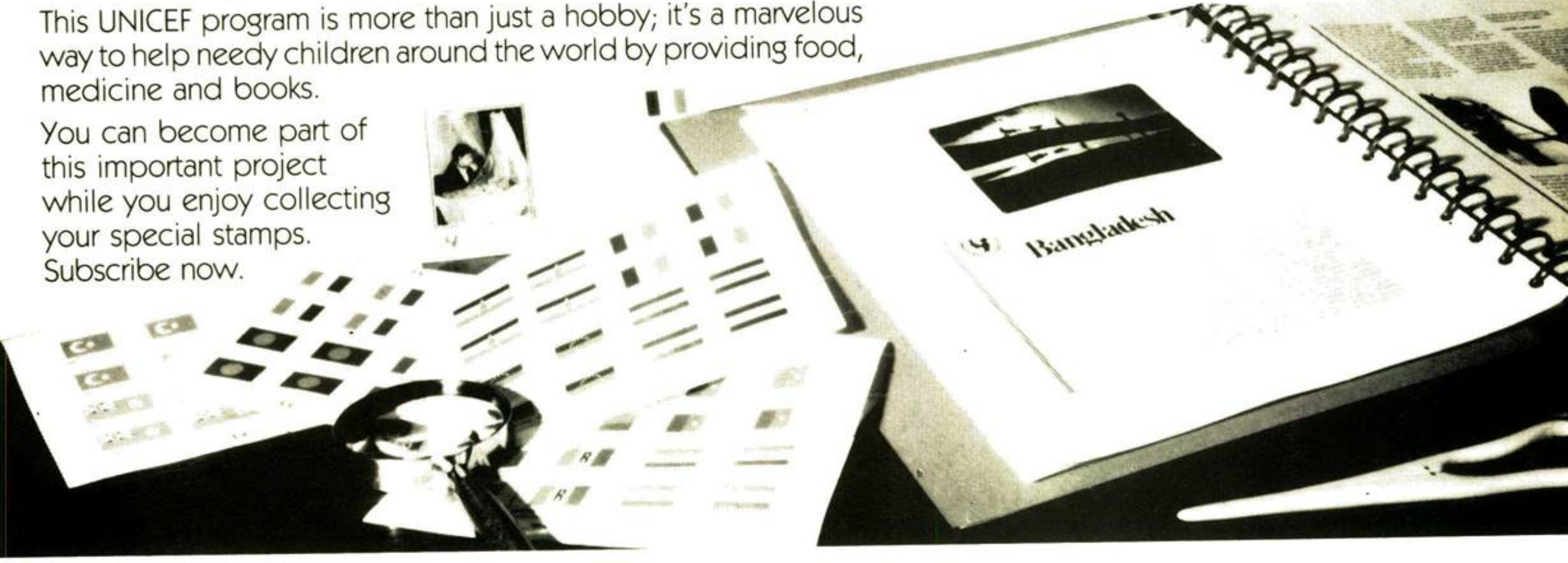

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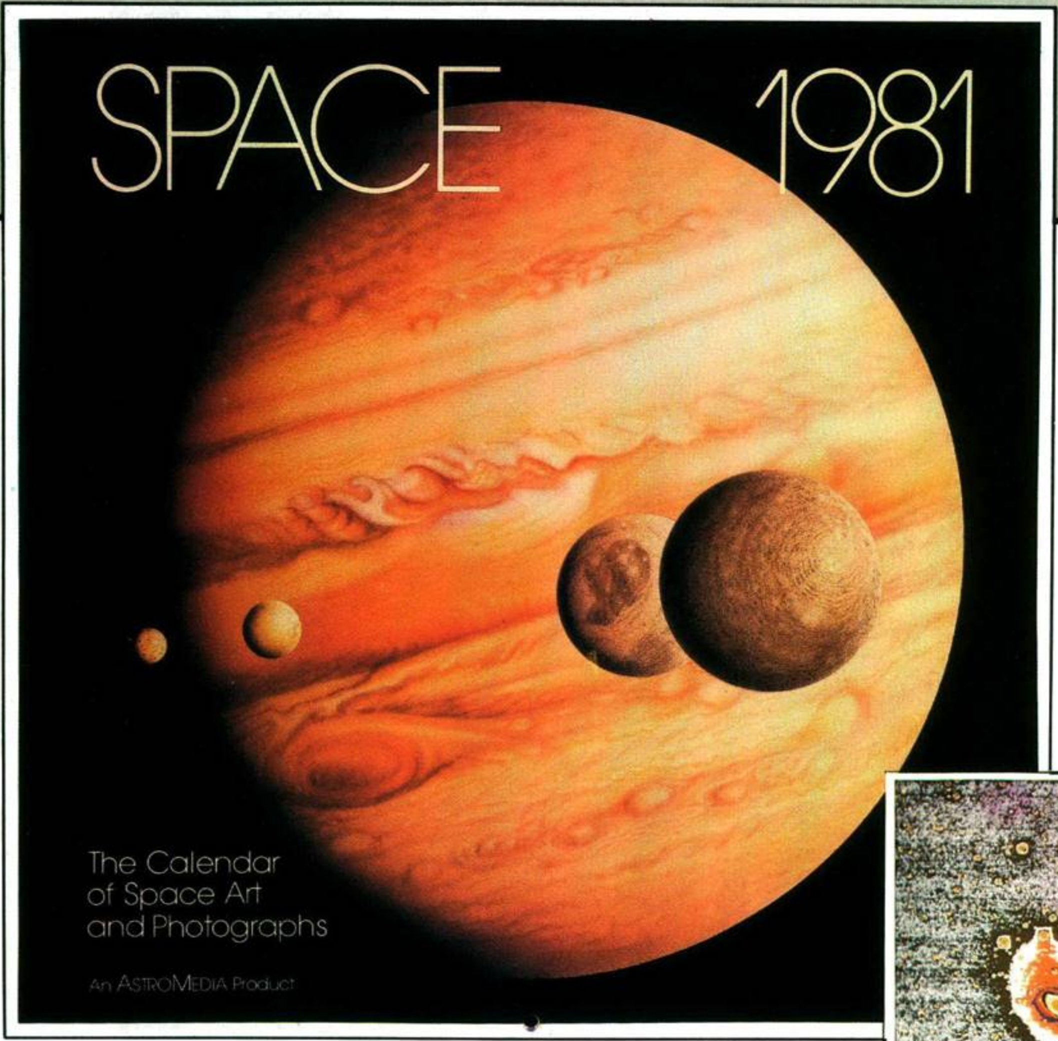

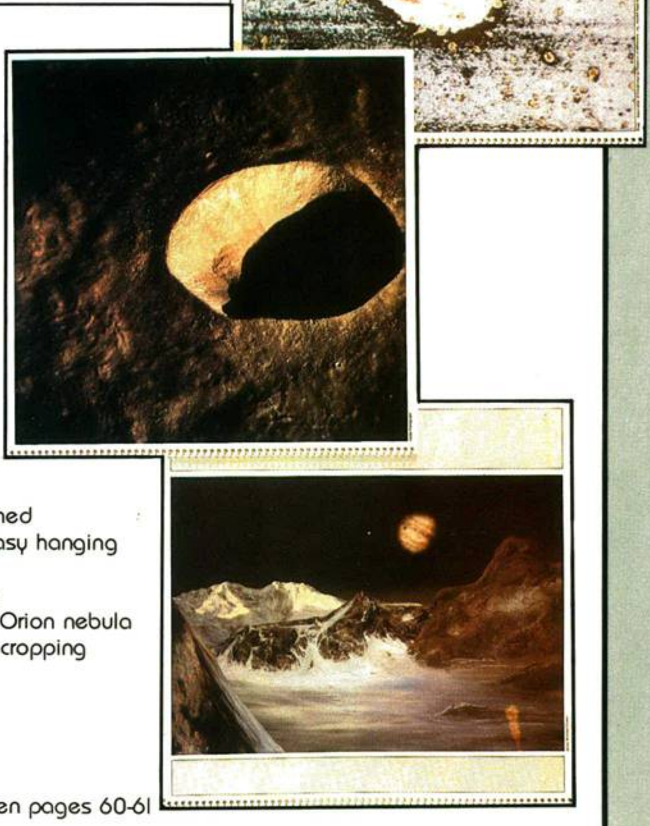

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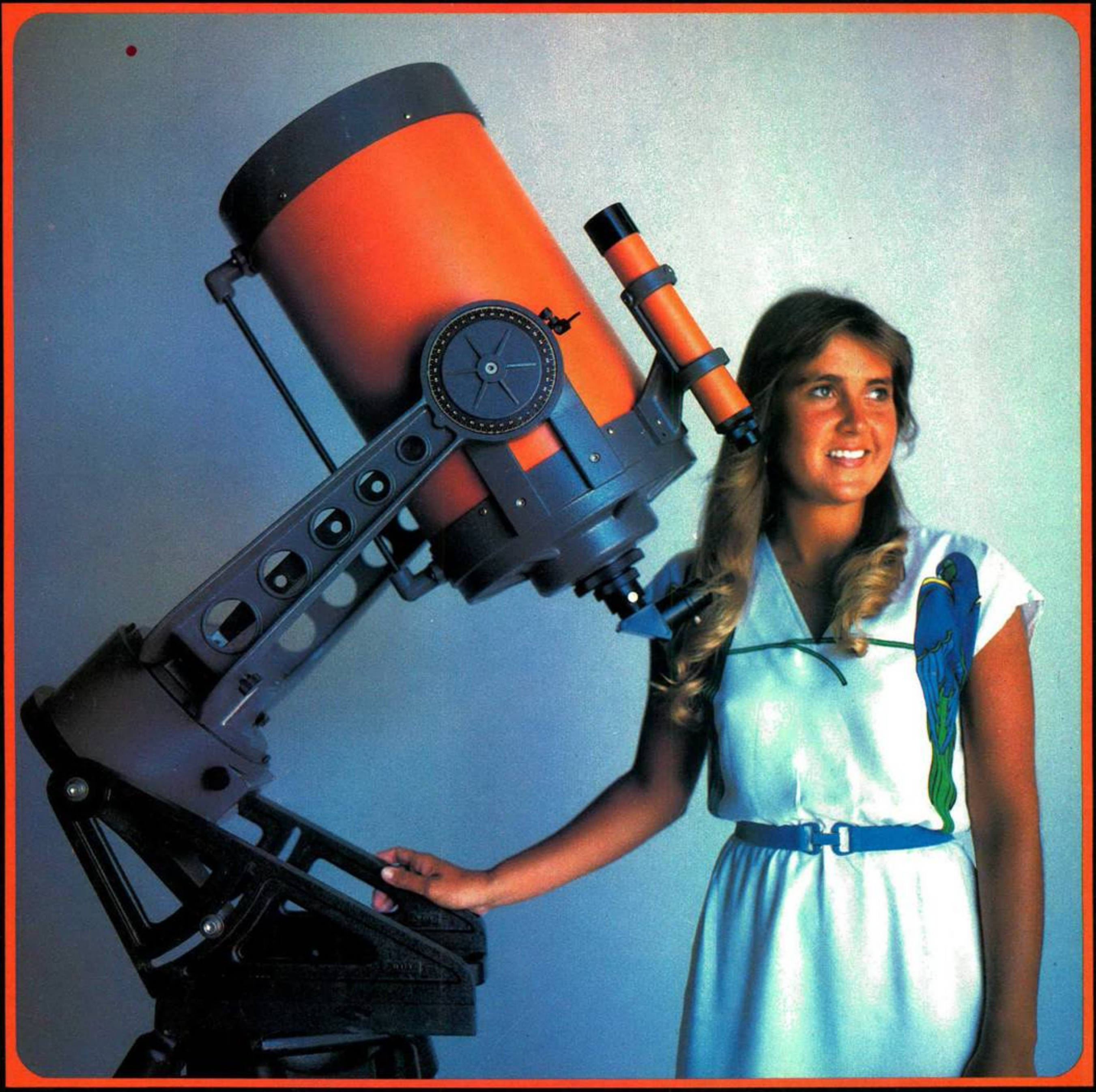

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